FOR THE INCREASE AND DIFFUSION OF KNOWLEDGE AMONG MEN

SMITHSONIAN INSTITUTION

WASHINGTON 1846

ANNUAL REPORT OF THE
BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND
CONDITION OF THE INSTITUTION
FOR THE YEAR ENDING JUNE 30

1917

WASHINGTON
GOVERNMENT PRINTING OFFICE

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30, 1917.

SMITHSONIAN INSTITUTION,
Washington, June 30, 1918.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1917. I have the honor to be,

Very respectfully, your obedient servant,

CHARLES D. WALCOTT, *Secretary.*

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2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1917.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1917.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1917.

THE SMITHSONIAN INSTITUTION.

June 30, 1917.

Presiding officer ex officio.—WOODROW WILSON, President of the United States.
Chancellor.—EDWARD DOUGLASS WHITE, Chief Justice of the United States.
Members of the Institution:

WOODROW WILSON, President of the United States.
THOMAS R. MARSHALL, Vice President of the United States.
EDWARD DOUGLASS WHITE, Chief Justice of the United States.
ROBERT LANSING, Secretary of State.
WILLIAM GIBBS MCADOO, Secretary of the Treasury.
NEWTON DIEHL BAKER, Secretary of War.
THOMAS WATT GREGORY, Attorney General.
ALBERT SIDNEY BURLESON, Postmaster General.
JOSEPHUS DANIELS, Secretary of the Navy.
FRANKLIN KNIGHT LANE, Secretary of the Interior.
DAVID FRANKLIN HOUSTON, Secretary of Agriculture.
WILLIAM COX REDFIELD, Secretary of Commerce.
WILLIAM BAUCHOP WILSON, Secretary of Labor.

Regents of the Institution:

EDWARD DOUGLASS WHITE, Chief Justice of the United States, Chancellor.
THOMAS R. MARSHALL, Vice President of the United States.
HENRY CABOT LODGE, Member of the Senate.
WILLIAM J. STONE, Member of the Senate.
HENRY FRENCH HOLLIS, Member of the Senate.
SCOTT FERRIS, Member of the House of Representatives.
ERNEST W. ROBERTS, former Member of the House of Representatives.
JAMES T. LLOYD, former Member of the House of Representatives.
ALEXANDER GRAHAM BELL, citizen of Washington, D. C.
GEORGE GRAY, citizen of Delaware.
CHARLES F. CHOATE, Jr., citizen of Massachusetts.
JOHN B. HENDERSON, Jr., citizen of Washington, D. C.
CHARLES W. FAIRBANKS, citizen of Indiana.
HENRY WHITE, citizen of Maryland.

Executive committee.—GEORGE GRAY, ALEXANDER GRAHAM BELL, ERNEST W. ROBERTS.
Secretary of the Institution.—CHARLES D. WALCOTT.
Assistant Secretary.—RICHARD RATHBUN.
Chief Clerk.—HARRY W. DORSEY.
Accountant and disbursing agent.—W. I. ADAMS.
Editor.—A. HOWARD CLARK.
Assistant librarian.—PAUL BROCKETT.
Property clerk.—J. H. HILL.

THE NATIONAL MUSEUM.

Keeper ex officio.—Charles D. Walcott, Secretary of the Smithsonian Institution.

Assistant secretary in charge.—Richard Rathbun.

Administrative assistant.—W. de C. Ravenel.

Head curators.—William H. Holmes, Leonhard Stejneger, G. P. Merrill.

Curators.—Paul Bartsch, R. S. Bassler, A. Howard Clark, F. W. Clarke, F. V. Coville, W. H. Dall, Chester G. Gilbert, Walter Hough, L. O. Howard, Aleš Hrdlička, Frederick L. Lewton, George C. Maynard, Gerrit S. Miller, Jr., Robert Ridgway.

Associate curators.—J. C. Crawford, W. R. Maxon, David White.

Curator, National Gallery of Art.—W. H. Holmes.

Chief of correspondence and documents.—

Disbursing agent.—W. I. Adams.

Chief of exhibits (Biology).—James E. Benedict.

Superintendent of buildings and labor.—J. S. Goldsmith.

Editor.—Marcus Benjamin.

Assistant librarian.—N. P. Scudder.

Photographer.—L. W. Beeson.

Registrar.—S. C. Brown.

Property clerk.—W. A. Knowles.

Engineer.—C. R. Denmark.

BUREAU OF AMERICAN ETHNOLOGY.

Ethnologist-in-charge.—F. W. Hodge.

Ethnologists.—J. Walter Fewkes, John P. Harrington, J. N. B. Hewitt, Francis La Flesche, Truman Michelson, James Mooney, John R. Swanton.

Special ethnologist.—Leo J. Frachtenberg.

Honorary philologist.—Franz Boas.

Editor.—Joseph G. Gurley.

Librarian.—Ella Leary.

Illustrator.—De Lancey Gill.

INTERNATIONAL EXCHANGES.

Chief clerk.—C. W. Shoemaker.

NATIONAL ZOOLOGICAL PARK.

Superintendent.—Ned Hollister.

Assistant Superintendent.—A. B. Baker.

ASTROPHYSICAL OBSERVATORY.

Director.—C. G. Abbot.

Aid.—F. E. Fowle, Jr.

Bolometric assistant.—L. B. Aldrich.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

Assistant in charge.—Leonard C. Gunnell.

REPORT

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION

CHARLES D. WALCOTT

FOR THE YEAR ENDING JUNE 30, 1917.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith the customary annual report on the operations of the Smithsonian Institution and its branches during the fiscal year ending June 30, 1917, including work placed by Congress under the direction of the Board of Regents in the United States National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, and the United States Bureau of the International Catalogue of Scientific Literature.

The general report reviews the affairs of the Institution proper and briefly summarizes the operations of its several branches, while the appendices contain detailed reports by the assistant secretary and others directly in charge of various activities. The reports on operations of the National Museum and the Bureau of American Ethnology will also be published as independent volumes.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

The Smithsonian Institution was created an establishment by act of Congress approved August 10, 1846. Its statutory members are the President of the United States, the Vice President, the Chief Justice, and the heads of the executive departments.

THE BOARD OF REGENTS.

The Board of Regents, which is charged with the administration of the Institution, consists of the Vice President and the Chief Justice of the United States as ex officio members, three Members of the Senate, three Members of the House of Representatives, and six citizens, "two of whom shall be residents in the city of Washington and

the other four shall be inhabitants of some State, but no two of them from the same State."

In the personnel of the board the only change was the appointment on January 15, 1917, of Hon. Henry White, of Maryland, to succeed Dr. Andrew D. White, of New York, who because of the infirmities of age felt compelled to resign after serving as Regent for nearly 29 years. The roll of Regents on June 30, 1917, was as follows: Edward D. White, Chief Justice of the United States, Chancellor; Thomas R. Marshall, Vice President of the United States; Henry Cabot Lodge, Member of the Senate; William J. Stone, Member of the Senate; Henry French Hollis, Member of the Senate; Scott Ferris, Member of the House of Representatives; Ernest W. Roberts, former Member of the House of Representatives; James T. Lloyd, former Member of the House of Representatives; Alexander Graham Bell, citizen of Washington, D. C.; George Gray, citizen of Delaware; Charles F. Choate, jr., citizen of Massachusetts; John B. Henderson, jr., citizen of Washington, D. C.; Charles W. Fairbanks, citizen of Indiana, and Henry White, citizen of Maryland.

The board held its annual meeting on December 14, 1916. The proceedings of that meeting, as also the annual financial report of the executive committee, have been printed, as usual, for the use of the Regents, while such important matters acted upon as are of public interest are reviewed under appropriate heads in the present report of the secretary. A detailed statement of disbursements from Government appropriations, under the direction of the Institution for the maintenance of the National Museum, the National Zoological Park, and other branches, will be submitted to Congress by the secretary in the usual manner, in compliance with the law.

FINANCES.

By the deposit of $4,000 derived from revenues during the year, the permanent fund of the Institution deposited in the Treasury of the United States now amounts to $1,000,000, the limit authorized by Congress, and is divided as follows:

Smithson fund	$727,640.00
Habel fund	500.00
Hamilton fund	2,500.00
Hodgkins fund	216,000.00
Rhees fund	590.00
Avery fund	14,000.00
Addison T. Reid fund	11,000.00
Lucy T. and George W. Poore fund	26,670.00
George K. Sanford fund	1,100.00
Total fund in the Treasury of the United States	1,000,000.00

Other resources.

Registered and guaranteed 4 per cent bonds of the West Shore Railroad Co., part of legacy of Thomas G. Hodgkins (par value)	$42,000.00
Coupon 5 per cent bonds of the Brooklyn Rapid Transit Co., due July 1, 1918 (cost)	5,040.63
Coupon 6 per cent bonds of the Argentine Nation, due Dec. 15, 1917 (cost)	5,093.75
Total invested funds	1,052,134.38

With the exception of $4,000 deposited in the Treasury, above noted, no other permanent investments were made during the year. These deposits consisted of interest accumulations and rentals only.

The principal revenues of the Institution being collectable July 1 and January 1 each year, a surplus of cash accumulated at these times. Instead of allowing this surplus to be idle in the Treasury, the plan has been adopted to invest such sums as may be spared in time certificates of deposit issued by strong financial institutions of this city. The rate of interest obtained on these certificates is 3 per cent per annum and it is believed that approximately $1,000 can be gained each year by this method.

The income of the Institution during the year, amounting to $88,649.52, was derived as follows: Interest on the permanent foundation, $61,490.59; contributions from various sources for specific purposes, $16,630; and from other miscellaneous sources, $10,528.93.

Adding the cash balance of $44,711.02 on July 1, 1916, the total resources for the fiscal year amounted to $133,360.54.

The disbursements, which are given in detail in the annual report of the executive committee, amounted to $124,127.98, leaving a balance of $9,232.56 in cash and on deposit in the Treasury of the United States June 30, 1917.

In addition to the above specific amounts to be disbursed by the Institution there was included under the general appropriation for printing and binding an allotment of $76,200 to cover the cost of printing and binding the Smithsonian annual report, and reports and miscellaneous printing for the Government branches of the Institution.

The Institution was charged by Congress with the disbursement of the following appropriations for the year ending June 30, 1917.

International exchanges	$32,000
International exchanges, deficiency act of Apr. 17, 1917	3,500
American ethnology	42,000
Astrophysical observatory	13,000
National Museum:	
Furniture and fixtures	25,000
Heating and lighting	46,000

National Museum—Continued.	
Preservation of collections	$300,000
Books	2,000
Postage	500
Building repairs	10,000
National Zoological Park	100,000
International Catalogue of Scientific Literature	7,500
Total	581,500

GENERAL CONSIDERATIONS.

Throughout its history the Smithsonian Institution has constantly cooperated with the executive departments and other establishments of the Government in all matters pertaining to scientific activities. Particularly during the period of the present world war has the Institution been of service in connection with many important measures. Every member of its scientific staff, every one of its 500 or more employees, has aided the Nation to the utmost in every possible manner. The laboratories and workshops of the Institution and its branches have been utilized to their fullest extent and routine affairs have taken second place whenever important national matters have needed attention. Your Secretary, as president of the National Academy of Sciences, as chairman of the military committee of the National Research Council, and as chairman of the executive committee of the National Advisory Committee for Aeronautics, has had opportunity to keep in close touch with the needs of the Nation and to give such advice as has been in his power, especially in connection with the development of aeronautics.

The Institution was particularly fortunate in having as former Secretary, Prof. S. P. Langley, who in 1896 gave to the world a practical demonstration of the feasibility of mechanical flight by a machine heavier than air propelled by its own power. To him the Nation to-day owes more than can be told, and as an indication of that debt his memory is fittingly preserved in the name "Langley Field," a tract of some 1,600 acres near Hampton, Virginia, where extensive experiments of the highest importance to the art of aviation are now being carried on. The Government has now been aroused to the supreme worth of airplanes, machines which Professor Langley 20 years ago foresaw would be of great service in times of war as well as peace. His prophecy has been fulfilled far beyond his hopes or dreams. The large machine with which his personal experiments ceased in 1903 proved its worth and its capability of actual flight during the past year. Change after change in the design of airplanes to adapt them for scouting, for fighting, and other military purposes has followed in rapid succession until now aerial battles are of daily occurrence and nations are looking ahead to their extended use under peace conditions.

As stated in my last report, the organization of the National Advisory Committee for Aeronautics has made unnecessary for the present the permanent establishment by the Smithsonian Institution of the Langley Aerodyanmical Laboratory. Every facility continues, however, to be afforded to Federal bureaus to study aviation models and records possessed by the Institution and, in particular, to consult the large Smithsonian Library on Aeronautics, together with a general card index of aeronautical literature.

There has recently been erected adjacent to the Smithsonian building a temporary structure for the use of the United States Signal Serivce especially for housing aeroplanes of various designs and aviation appliances.

The executive committee of the National Advisory Committee has held monthly meetings during the year, and many problems of deep importance have been discussed.

Upon the recommendation of the committee there was organized by the Council of National Defense the "Aircraft Production Board," "to consider the situation in relation to the quantity production of aircraft in the United States and to cooperate with the officers of the Army and Navy and of other departments interested in the production and delivery to these departments of the needed aircraft in accordance with the requirements of each department."

The committee also recommended to the Government the adoption of a continuing program for the training of aviators and the production of airplanes and the establishment of schools and an adequate organization and personnel of regular officers, both in the Army and Navy for the efficient use of aircraft and direction of the aviators provided for. As a result of the committee's activities the advance in aerial preparedness has been accelerated.

The committee has established a research laboratory at Langley Field, Virginia, for the carrying on of scientific investigations. Among the several subcommittees engaged in the study of aeronautic problems are those on aerial mail service, aero torpedoes, aircraft communication, airplane mapping, relation of the atmosphere to aeronautics, standardization of specifications for aeronautic materials and aeronautic nomenclature, specifications for aeronautic instruments, radiator design, motive power, and safe design, construction, and navigation of aircraft.

The second annual report of the National Advisory Committee for Aeronautics was published during the year in a volume of 630 octavo pages, including technical reports on "General specifications covering requirements of aeronautic instruments," "Nomenclature for aeronautics," "Mufflers for aeronautics," "Gasoline carbureter design," and "Experimental researches on the resistance of air."

RESEARCHES AND EXPLORATIONS.

The usual activities were continued during the past year in advancing one of the fundamental objects of the Smithsonian Institution, the *increase of knowledge*. In this work various explorations and researches were inaugurated or participated in by the Institution and its branches, covering practically all divisions of astronomical, anthropological, biological, and geological science. The extent of these explorations and researches during the history of the Institution covers a wide range, although a great deal more of most important work could have been accomplished had adequate funds been available. Friends of the Institution have generously aided this work, particularly during the last few years, through the contribution of funds for specific purposes, but much yet remains undone, and opportunities for undertaking important lines of investigation are constantly being lost through lack of means to carry them into execution.

Several proposed expeditions to various parts of the world have been temporarily delayed by the war in Europe.

I will here mention only briefly some of the recent activities of the Institution in these directions, and for details of other researches and explorations may refer to the appendices containing the reports of those directly in charge of the several branches of the Institution and also to the accounts given in the customary pamphlet review of this work published each year in the Smithsonian Miscellaneous Collections.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES.

In continuation of geological work carried on by me for several years past in the Canadian Rocky Mountains, I was engaged during the summer and early fall of 1916 in field investigations on the Continental Divide forming the boundary between Alberta and British Columbia, south of the Canadian Pacific Railway. The very heavy snowfall of the previous winter, together with frequent snow and rain squalls during the summer, had made the conditions unusually favorable for taking photographs, the air being exceptionally pure and clear during the field season, conditions, however, very unfavorable for geological investigations. A large number of photographs were secured, including a number of panoramic views made on continuous films 8 feet in length.

The sections examined and measured extend from the Mount Assiniboine region southwest of Banff, Alberta, northwest to the Kicking Horse Pass, where the Canadian Pacific Railway has bored a double loop through the mountains on the north and south sides of the pass.

The season's work was undertaken with two principal objects in view: First, to determine, if possible, the base line of demarcation between the Lower and Middle Cambrian; and second, to locate the exact horizon of a Cambrian subfauna (*Albertella*) that had in its entirety been found only in drift bowlders in the Kicking Horse Valley east of Wapta Lake.

One of the important incidental results obtained was the discovery at Wonder Pass of a great overthrust fault by which the basal Cambrian rocks forming the mountains on the west side of the pass have been thrust eastward over upon the limestones of the Devonian, shown in the slope on the east side of the pass. The thrust along this fault has carried the rocks forming the main range of the Rockies in this area several miles to the eastward. The fault crosses through Wonder Pass and then curves to the northwest, southeast of Magog Lake, to the great cliff forming the northern extension of the Assiniboine massif. During the million or more years that the agencies of erosion had been wearing away the great mass of rocks above the fault, mountain peaks, canyons, and ridges have been carved and polished by frost, snow, and the grinding force of huge glaciers. The glaciers have now retreated to a point near their origin, high up on the mountains, but they have left behind them basins that are filled with beautiful lakes, such as Magog, Sunburst, and Ross.

The line of demarcation between the Lower and Middle Cambrian was found to be high up in the section on the face of the cliffs at Wonder Pass, and throughout the Assiniboine massif.

While camped on Magog Lake, below Mount Assiniboine, some marvelous reflections of the peak in the waters of the lake were seen in the quiet of the early morning. The changes in the "cloud banners," at the peak occur very rapidly. These views led us to regard the grand pyramid of Mount Assiniboine as the Matterhorn of America.

Northwest of Banff the broad valley of the Bow has been eroded diagonally back through the massive scarf of the overthrust massif and thus exposed to erosion the heart of the great arch that had its crest over the region now occupied by Mount Victoria and other peaks of the Bow Range.

Some photographic views were secured looking south across the Bow Valley into the heart of the Rockies. A view of Pinnacle Peak tells the story of the tremendous power of erosive agencies, where the colossal quartzites and limestones are shattered and eroded into the most fantastic forms.

West of Pinnacle Peak, at the head of Paradise Valley, Mount Hungabee rises in a terraced wall 4,000 feet above the glacier at its foot, while another glimpse of these great cliffs is seen under Mount

Lefroy, where the melting snows cascade down as a beautiful brook over the quartzite ledges.

At last, in the cliffs above Ross Lake the *Albertella* fauna was located in situ, and from the slopes above the lake a panoramic view was taken of Mount Bosworth, above Kicking Horse Pass on the Continental Divide. Although only 9,083 feet in height, Mount Bosworth exposed in its slopes over 12,000 feet in thickness of bedded rocks that constitute one of the best sections of the Cambrian rocks found in the Canadian Rockies.

Considerable collections of Cambrian fossils were obtained by myself and Mrs. Walcott, who accompanied and worked with me throughout the entire trip, before the storms of late September drove us back to Banff and ended the research for the season.

Many of the photographs taken in this wonderful region are reproduced in one of the publications of the Institution.[1]

GEOLOGICAL FIELD STUDIES.

Dr. George P. Merrill, head curator of geology in the National Museum, devoted several days of the summer vacation period in 1916 to visiting the gem and feldspar quarries of Auburn, Topsham, and neighboring areas in Maine. While nothing new was secured, he was able to add interesting material to the Museum exhibit illustrating the character and association of the pegmatite dikes, which is now being installed in the Museum.

HUNTING GRAPTOLITES IN THE APPALACHIAN VALLEY.

The great value of the extinct organisms known as graptolites in determining the age of geological formations which contain few and often no other kinds of fossils, has been proved time and again. During the summer of 1916 Dr. R. S. Bassler and Mr. C. E. Resser, both of the division of paleontology, United States National Museum, had occasion to test this particular group of fossils in the course of a study of the Cambrian and Ordovician shale formations of western Maryland. They report that—

> Recent excavations along the Western Maryland Railroad, in the great shale belt just west of Williamsport and extending north and south for hundreds of miles, exposed these rocks to such advantage that it was thought possible enough fossils could be found in them to determine their exact geologic age and structure. However, no fossils of any kind were found after much search. It was then decided that the rocks were either barren of organic life or the cleavage produced in the strata by the great forces resulting in their present folded condition destroyed all traces of fossils.
>
> Finally a fold of black shale was observed and at the point where the cleavage and the bedding planes coincided, abundant graptolite remains were

[1] Smithsonian Miscellaneous Collections, vol. 66, No. 17, 1917.

discovered. The species which were collected proved to be of such typical Trenton forms that there could be no doubt of the Middle Ordovician age of this particular shale. Limestones known to be much older outcrop so short a distance to the east of this that a great fault or displacement between the two kinds of rocks is clearly indicated.

With these facts in hand, the fault was traced for a distance of 30 miles north and south, thus again showing that the graptolites proved the key to the geologic structure of the region.

EXPLORATIONS IN THE OHIO VALLEY FOR FOSSIL ALGAE AND CORAL REEFS.

Through the extensive studies of the Secretary for several years past, the collections of the National Museum are rich in limestone-forming pre-Cambrian algae—a low order of water plants that secrete lime or silica. An instructive series of these fossils has been placed on exhibition, but in order to show the geologic occurrence and evolution of this group of plants it was necessary to supplement the pre-Cambrian forms with specimens of more recent age. Accordingly Dr. R. S. Bassler, curator of paleontology, spent some weeks in the Ohio Valley, particularly in the blue grass region of Kentucky, in a search for large exhibition specimens, and in a study of their mode of occurrence. He was successful in procuring a number of showy exhibition specimens as well as numerous study collections.

More difficult, however, was the discovery and quarrying of a fossil coral reef suitable for exhibition in the Museum. Coral reefs are known at several horizons in the Paleozoic rocks of the Ohio Valley but they are seldom so exposed that an instructive section can be quarried out without injury to the specimens. A great reef of corals outcrops in the strata along the banks of Chenoweth Creek at Jeffersontown, near Louisville, Kentucky, and this was selected to furnish an exhibit for the Museum. A section of the stratified rocks 6 feet by 10 feet was bodily quarried out of the bank, and these strata with their contained corals were later set up in the exhibition hall of paleontology.

The lowest layer of limestone is composed largely of fossil brachiopod shells. Next above is a layer with scattered corals belonging to a long-tubed species (*Columnaria calcina* Nicholson), probably torn by waves from a near-by coral reef. Overlying this is a limestone stratum largely made of the twiglike stems of stony Bryozoa (Trepostomata).

The main reef of corals is chiefly composed of the rounded heads of three species of honeycomb corals, some with radial partitions in the tubes (*Columnaria alveolata* Goldfuss), others without such partitions (*Columnaria vacua* Foerste), and still others with spongy walls (*Calapoecia cribriformis* Nicholson). Large stems of fluted or

nodular Hydrozoa (*Beatricea*) are scattered among the honeycomb coral masses.

Horn corals (*Streptelasma rusticum* Billings) are to be seen in both the lower and upper coral beds. The spaces between the limestone layers and also between the heads of coral were filled with clay which contained many other examples of fossil life.

Another coral reef in central Kentucky composed of a single species (*Stromatocerium pustulosum* Safford) was investigated and several massive and complete specimens excavated for exhibition. The smallest of these was several feet in diameter. These conical coral masses are restricted to a single layer of limestone, on which account they serve to identify the bed from place to place. This coral reef occurs in the Trenton limestone and fine outcrops occur around Lexington, Kentucky, and it has been noted at many localities in central Kentucky and central Tennessee.

EXAMINATION OF ANCIENT HUMAN REMAINS IN FLORIDA.

A good deal of public and scientific interest was aroused by the finding of human remains in Florida under conditions which seemed possibly to indicate extreme age. It was therefore desirable that a critical examination be made of the bones and their environment. Accordingly, on the invitation of Dr. E. H. Sellards, State geologist of Florida, and as his guest, Doctor Hrdlička, of the United States National Museum, spent four days in the latter part of October, 1916, at Vero, Florida, where his time was devoted to the study of the site from which certain human bones described by Doctor Sellards were obtained, and to a preliminary examination of the bones themselves.

Doctor Hrdlička reports as follows:

Laborers were engaged, and with their help there was made a clean exposure about 100 feet in length of the geological deposits in close proximity to the localities where the human bones had been discovered. This afforded a comprehensive and enlightening view of the formations involved.

The two human skeletons had been found in the south bank of a recently excavated drainage canal. They occurred one in fairly close proximity to, and the other within the broad, shallow bed of a small fresh-water stream, now drained by a lateral cut from the canal. The former lay in dark and somewhat indurated sands, the latter for the most part at the base of the muck deposit of the stream bed, and between this and the next older stratum. A few smaller bones, which probably belonged to the second skeleton, were found at about the same level a short distance from the rest of the remains in an elevation of the lower sandy layer.

The first skeleton lay at a depth of 2½ feet, the second at a depth of 2 to 3½ feet from the surface. The deposits above the first skeleton consisted partly of somewhat indurated and partly of ordinary sands, overlaid by a layer of marl. The marl when freshly exposed was found to be of the consistency of

fresh mortar, but on longer exposure hardened to fairly solid rock. Above skeleton No. II there was only muck and irregular sandy patches.

Skeleton No. I is that of a woman, probably adult; skeleton No. II that of an adult man of somewhat advanced years. The bones of the former lay close together; those of the latter were dissociated, though lying within a moderate-sized ellipse. Broken pottery, bone and stone implements, and stone chips were found in the same strata, more particularly in the muck layers, with the human bones.

Besides the two skeletons, single bones of three additional human bodies—one a child, one a young person, and one adult—were discovered in the vicinity.

The human bones were considerably mineralized, and in the same strata in which they occurred are found many bones of long-extinct animals, such as mastodons, tapirs, etc.

Due to the presence of the fossil animal bones in the same strata with the human remains, and to the mineralization of the latter, the opinion was advanced that the human remains were of the same age as the animal bones, which would relegate them to the early part of the Quaternary.

This is not sustained by an anthropological study of the case and of the remains. The human bones show no signs of weathering, gnawing, or trampling, and the two skeletons were represented by so many parts that the only satisfactory explanation of the conditions can be found in the assumption that the remains are those of intentional burials.

The pottery and the bone and stone implements are all identical with similar artifacts of the Florida or southeastern Indians, while the human bones themselves show, without exception, modern features, with numerous characteristics which permit their identification also as Indian.

The conclusions arrived at are that the Vero finds represent another of those cases, which are bound to occur from time to time, where the circumstances seem to point to antiquity of the human bones, but where a thorough, all-sided inquiry shows that the mass of the evidence is decisively against such an assumption.

Following the visit to Vero, Doctor Hrdlička made a trip to Fort Myers, Florida, and to several of the outlying keys, where human remains were reported. The particular object of this trip was to visit a small island off Fort Myers known as the Demorest or Demere Key, on which, according to information obtained from Mr. Sam L. King, of Bristol, Tennessee, human bones could be found "imbedded in concretionary materials." Concerning these remains Doctor Hrdlička says:

Demere Key, the surface of which measures about 15 acres, was originally a low and swampy island, like all of the small keys in the vicinity, but a larger part of its surface was in the course of time artificially elevated by the Indians, by means of shells, sand, and soil, for the purpose of habitation and cultivation. Along the middle of this large artificial elevation runs a remarkable platform about 80 feet long, the eastern boundary of which is supported by a still fairly well preserved, well-made wall of conch shells. This structure has been briefly reported by Cushing and by Mr. Clarence B. Moore, but its origin is in doubt. At a short distance northeast of this elevation there is a low, irregular heap which contains numerous Indian burials. On examining the surface of this heap it was found to consist of shells, detritus, sand, and vegetable matter, and to be everywhere more or less consolidated to the depth of from 6 to 18 inches. The consolidation was such that in many places it was very hard to penetrate

the crust with an ordinary mattock. Within this crust, on breaking parts of it off and turning them over, were found numerous human bones, including some more or less defective skulls. Beneath the crust was white sand, which also contained many bones, with a few Indian ornaments and fragments of pottery. The consolidated crust differed in composition. For the larger part it was coquina, of just about such a composition as beach accumulations along the sea; but in other places the solidified part consisted almost entirely of white sand, while in still others it was a dark concretionary mass including shells, sand, and vegetable matter, besides the bones. The human bones, though evidently more or less changed, were not yet petrified; and the mound as a whole appears to have no claim to antiquity greater than perhaps a few hundred years; but its surface offers a fine example of what favorable conditions can accomplish in no great space of time in the way of consolidation and inclusion into rock of human remains.

BIOLOGICAL WORK IN CUBA AND HAITI.

Mr. John B. Henderson, a Regent of the Institution, and Dr. Paul Bartsch, curator of marine invertebrates, spent the last half of March in the region about the Guantanamo Naval Station in eastern Cuba, collecting a large quantity of very interesting land shells, birds, plants, fossils, and marine invertebrates. The month of April was spent in Haiti, where they thoroughly explored the Cul-de-Sac region, the north coast of the western peninsula, and the coastal range from the Cul-de-Sac north as far as San Marcos. They secured many interesting specimens of land and fresh-water mollusks, several new birds, some very interesting cacti and other plants, and a general invertebrate collection from this much-neglected island. A large series of interesting photographs was also made, many of which will be used in a report on the expedition which the explorers hope to publish in the near future.

BOTANICAL EXPLORATIONS IN THE HAWAIIAN ISLANDS.

During the summer of 1916, from June to November, Mr. A. S. Hitchcock, custodian of the section of grasses of the division of plants in the National Museum, traveled in the Hawaiian Islands studying and collecting the flora, especially the grasses. Concerning his explorations Mr. Hitchcock says:

The islands are all of volcanic origin and the rock is lava except a very little that is coral formation. Kauai, the geologically oldest island, shows the greatest effect of erosion, the deep canyons rivaling in beauty the Grand Canyon of the Colorado. On the island of Hawaii are the two highest peaks of the group—Mauna Kea, 13,825 feet, and Mauna Loa, 13,675 feet in height. Above 10,000 feet there is scarcely any vegetation upon these peaks, especially upon Mauna Loa, which is made up of comparatively recent lava.

The important agricultural industries are the raising of sugar, live stock, and pineapples. The cultivated trees and shrubs are of great variety and beauty, and are drawn from all tropical and subtropical lands. One of the introduced trees of great economic importance is the algaroba tree, or kiawe, as

the Hawaiians call it. It is found in a belt on the lowlands along the shores of all the islands and occupies the soil almost to the exclusion of other plants. The pods are very nutritious and are eagerly eaten by all kinds of stock. The flowers furnish an excellent quality of honey. The prickly-pear cactus has become extensively naturalized in the dryer portions of all the islands. The ranchmen utilize this for feed when other kinds become scarce, the cattle eating the succulent joints in spite of the thorns. Two introduced shrubs now occupy extensive areas and have become great pests. These are guava, whose fruit furnishes the delicious guava jelly, and lantana, with clusters of handsome parti-colored flowers.

The indigenous flora is highly interesting though not abundant in species. Two of the commonest trees are the ohia and the koa. The former, also called ohia lehua and lehua, resembles, in the appearance of the trunk, our white oak, but bears beautiful clusters of scarlet flowers with long-protruding stamens. The koa produces a valuable wood much used in cabinetmaking, now becoming familiar through its use for making ukuleles. Among the peculiar plants of the islands is the silversword, a strikingly beautiful composite with glistening silvery leaves, which grows only on the slopes of cinder cones in the crater of Haleakala and in a few very limited localities on Hawaii. The family Lobeliaceae is represented by about 100 species belonging to 6 genera. The numerous arborescent species are very peculiar and characteristic. Many of them form slender trunks like small palms, crowned with a large cluster of long narrow leaves. The trunks of some species are as much as 30 or 40 feet high, and the large bright colored flowers are sometimes remarkably beautiful.

The indigenous grasses of the Hawaiian Islands are not numerous. Three peculiar species of Panicum inhabit the open bogs formed on the tops of many of the high mountains in the wet zone such as Mount Eeka and Mount Kukui in west Maui, some of the peaks of Molokai and Oahu, and Waialeale in Kauai, that upon the latter covering in all several square miles. These bogs are found near the summits or ridges in the regions of heavy rainfall, are devoid of trees and shrubs, and harbor a peculiar vegetation.

CINCHONA BOTANICAL STATION.

Recently the Institution has acquired a three years' lease of the Cinchona Botanical Station at Jamaica, comprising about 10 acres of land, with offices, laboratories, and other buildings, for the furtherance of our knowledge of West Indian botany. Assignments of botanists who desire to prosecute studies there are made on the recommendation of organizations which have cooperated with the Institution in securing the use of this important field for botanical investigations.

BIOLOGICAL WORK IN CHINA.

Mr. Arthur de C. Sowerby has continued his work in northeastern China though conditions have been so unsettled as to make collecting extremely difficult. A shipment of natural history specimens to the Museum from Mr. Sowerby received May 27, included 186 bird skins, 44 mammals, 1 reptile, 16 fishes, and other miscellaneous natural history objects.

EXPLORATIONS IN SANTO DOMINGO.

Dr. W. L. Abbott, whose energies for nearly 30 years past have been devoted to explorations in the Old World, made a short visit to Santo Domingo (the scene of his earliest expedition, in 1883), where he spent a few weeks in late summer and fall, 1916, at the eastern end of the island, chiefly in the vicinity of the Bay of Samana, with trips to several localities in the highlands of the interior, notably at Constanza and El Rio. On this expedition he made a very interesting collection of mammals, birds, reptiles, mollusks, insects, and Indian relics.

In the coast region, Doctor Abbott investigated numerous caves in search of remains of an extinct mammalian fauna. One of the most interesting mammals whose remains were found in these caves is a large rodent, described from a freshly killed specimen in 1836, but not captured since then. Whether it is extinct or not is at present an uncertainty. At San Lorenzo Bay, on the south side of the Bay of Samana, there are "many precipitous limestone hills," which, Doctor Abbott writes, are "literally honeycombed with caves. The cave (usually inhabited) near the pier of the abandoned railroad is full of shell heaps, and contains many Indian carvings, more or less obliterated by smoke and lime deposits." Here he uncovered 200 or more archeological objects, including terra-cotta images, fragments of pottery, stone pestles, carved stone plates, and similar material.

After exhausting the caves in the vicinity of Samana, Doctor Abbott visited the mountains of the interior, where, at El Rio, he made a most surprising discovery in the bird fauna. He writes "I had heard of a very small 'parrot' which lived in flocks in the pines on the pine cones. I suspected a crossbill—said to occur here at Jarabocoa, below 2,000 feet, but the pair I shot were at near 5,000 feet." The bird proved to be a veritable crossbill and, what was most extraordinary, a form closely related to the white-winged crossbill, a species restricted in the breeding season to the Boreal zone of North America (from Alaska to the higher Adirondacks), migrating in winter at rare intervals as far south as North Carolina.

The series of birds totaled about 250 specimens, of 50 or more species, over 30 of which are peculiar to the island. The indigenous species of this island have long constituted the Museum's chief desiderata among the birds of the West Indies, hence Doctor Abbott's collection has proved of great interest, aside from the special discoveries mentioned above.

EXPEDITION TO CELEBES.

Through the generosity of Dr. W. L. Abbott, associate in zoology in the Museum, Mr. H. C. Raven has continued to make natural

history and ethnological collections in Celebes. In April the Museum received a shipment of ethnological objects from Mr. Raven, including native fish traps, baskets, cloth, rope, hats, dishes, blowguns used for hunting birds, and a curious native musical instrument.

COLLINS-GARNER CONGO EXPEDITION.

Early in 1917 an expedition with the title of the Collins-Garner Congo expedition in the interests of the Smithsonian Institution, left for the French Congo and neighboring parts of west Africa. Mr. C. R. W. Aschemeier, of the department of biology, National Museum, is representing the Smithsonian Institution and the Museum as natural history collector. All of the natural history specimens collected by the expedition will come to the National Museum. The other members of the expedition are Mr. Alfred M. Collins, of Philadelphia, chief; Prof. Richard L. Garner, of New York, who is making special studies concerning apes and monkeys, manager; and Prof. Charles W. Furlong, of Boston, scientist, artist, and explorer.

RESEARCH CORPORATION.

In my annual reports for several years past I have called attention to the Research Corporation organized in 1912 under the laws of New York State, and having as its officers and directors a group of men particularly interested in the development of the industrial arts. The present Secretary of the Smithsonian Institution is one of the directors and a member of the executive committee. The certificate of incorporation declares it to be the purpose of the corporation to—

> Provide means for the advancement and extension of technical and scientific investigation, research, and experimentation by contributing the net earnings of the corporation over and above such sum or sums as may be reserved or retained and held as an endowment fund or working capital, and also such other moneys and property belonging to the corporation as the board of directors shall from time to time deem proper, to the Smithsonian Institution, and such other scientific and educational institutions and societies as the board of directors may from time to time select, in order to enable such institutions and societies to conduct such investigation, research, and experimentation.

The principal income of the corporation is at present derived from royalties for the use of the Cottrell process for the electrical precipitation of suspended particles. Dr. F. G. Cottrell, the inventor of this process, offered his patents to the Smithsonian Institution, but since is was not practicable for the institution to administer them commercially, the Research Corporation was organized for that purpose. The process is now in successful use by a score of smelting and refining companies and other industrial plants and the financial condition of the corporation is very gratifying.

The corporation seeks to do for industrial arts what some other institutions are now doing for the sciences generally, for medicine, and for the improvement of social conditions. There has now been established an annual fellowship "open to general competition for the purpose of encouraging and assisting scientists in the prosecution of their investigations. To the successful competitor, the corporation offers an honorarium of twenty-five hundred dollars and the assistance of the corporation in securing the most favorable opportunity for prosecuting the particular object of study."

The Cottrell process in operation has been described in publications of the Smithsonian Institution. The precipitation processes and their applications have been briefly described as follows:

> Electrical precipitation consists of the removal of suspended particles from gases by the aid of electrical discharges. The precipitation process operates by passing the gases carrying the suspended, finely divided particles between two systems of electrodes, one of which is made to carry a negative electrical charge while the other carries a positive charge. In ordinary practice the negative electrodes are small in size, such as iron wires or chains, and the positive electrodes are large, such as iron plates or pipes. The gases are divided into several channels and passed through the space between the wires and the plates or pipes, in the latter case each pipe having a wire placed along its longitudinal axis. The electrodes are charged by being connected with a source of high voltage electricity, consisting ordinarily of a high voltage transformer for increasing the electricity up to the working voltage which varies with the size and character of the installation from 20,000 to 100,000 volts; a rectifier for changing alternating current into direct current, and a switchboard provided with the necessary standard control equipment. The suspended particles while passing between the electrodes become electrically charged and are then driven to the plates or the inner surface of the pipes by the forces of the electric field. A common example of the application of the process is in the precipitation of minute particles containing copper, silver, gold, lead, zinc, and other valuable metals ordinarily carried away from smelting and refining furnaces which may by this process be recovered from such gases without interfering with the operation of the plant. The recovered dust or fume, in such cases, is often valuable and constitutes a large financial saving. In many other industrial operations where noxious gases, fumes, or dusts are given off, the process has been successfully applied, some of the materials precipitated being sulphuric, nitric, and hydrochloric acids; arsenic, bleaching powder, lead, zinc, and other poisonous materials.

NATIONAL RESEARCH COUNCIL

As stated in my last report, the National Research Council was organized by the National Academy of Sciences, the President of the United States appointing the representatives of the Government and authorizing the appointment of other members by the president of the academy. There were thus brought together about 50 members representing various branches of science, and they were subdivided in several subcommittees. Joint committees were also formed in

cooperation with national scientific societies. The Research Council has since become a part of the Council of National Defense and operates in coordination with that body. In the membership of the Research Council are several of the scientific staff of the United States National Museum, your Secretary being vice chairman of the council and chairman of the military committee.

With the preparations for actual participation by the United States in the world war, the council became an important factor in the scientific work of the Government. On February 29, 1917, the Council of National Defense adopted the following resolution:

> *Resolved*, That the Council of National Defense, recognizing that the National Research Council, at the request of the President of the United States, has organized the scientific forces of the country in the interest of national defense and national welfare, requests that the National Research Council cooperate with it in matters pertaining to scientific research for national defense; and to this end the Council of National Defense suggests that the National Research Council appoint a committee of not more than three, at least one of whom shall be located in Washington, for the purpose of maintaining active relations with the director of the Council of National Defense.

Since that time the National Research Council has served as the department of science and research of the Council of National Defense and in such capacity has been charged with the organization of scientific investigations bearing on the national defense and on industries affected by the war.

Shortly after this action Dr. George E. Hale, chairman of the council, initially undertook the organization of research activities in direct cooperation with the United States Government and its various departments. Office accommodations were provided for chemistry, engineering, medicine and hygienic, and physics committees of the council, and arrangements were made to provide such accommodations also for the agriculture and psychology committees. Dr. Robert A. Millikan, chairman of the physics committee, was appointed vice chairman of the council and consented to give his entire time, upon leave of absence from the University of Chicago, to work in Washington as the executive officer of the council. Offices in New York were retained with the secretary, Dr. Carey T. Hutchinson, in charge.

Particular mention may perhaps be made of the appointment of a foreign service committee of the council and of its important mission and work as a direct aid in acquainting investigators in this country with the scientific problems which have been confronted both in military and industrial pursuits in England and France.

Two other committees of the council have been especially organized as the result of the cooperation brought about with the Council of National Defense; one a committee on navigation and nautical instru-

ments, appointed upon the request of the General Munitions Board and the other a committee on relations with State research councils, appointed to consider and report upon desirable means of cooperation between the Council and State research committees.

OFFICERS OF THE COUNCIL.

George E. Hale, chairman; Charles D. Walcott, first vice chairman; Gano Dunn, second vice chairman; R. A. Millikan, third vice chairman and executive officer; Cary T. Hutchinson, secretary.

EXECUTIVE COMMITTEE.

J. J. Carty, chairman.

Marston T. Bogert.
Russell H. Chittenden.
Edwin G. Conklin.
Gano Dunn.
George E. Hale.
Van H. Manning.
R. A. Millikan.
Arthur A. Noyes.
Raymond Pearl.
Michael I. Pupin.
S. W. Stratton.
Victor C. Vaughan.
Charles D. Walcott.
William H. Welch.

The following members and new committees have been added to the council since my last report:

LIST OF NEW MEMBERS.

Carl L. Alsberg.
Joseph S. Ames.
Admiral William S. Benson.
Walter B. Cannon.
John M. Clarke.
Howard E. Coffin.
William M. Davis.
Arthur L. Day.
Henry H. Donaldson.
William F. Durand.
Rear Admiral Ralph Earle.
John R. Freeman.
Hollis Godfrey.
Rear Admiral Robert S. Griffin.
Herbert C. Hoover.
Franklin H. Martin.
John C. Merriam.
Eliakim H. Moore.
Frederick H. Newell.
George O. Smith.
Lewis B. Stillwell.
Robert W. Wood.

LIST OF COMMITTEES.

Military committee.
Agriculture committee.
Committee on Anthropology.
Botany committee.
Chemistry committee.
Food committee.
Committee on gases used in warfare.
Committee on Industrial Research.
Committee on Medicine and Hygiene.
Committee on Optical Glass.
Physiology committee.
Committee on Relations with State Research Councils.
Aeronautics committee.
Anatomy committee.
Astronomy committee.
Committee on census of research.
Engineering committee.
Foreign service committee.
Geography committee.
Geology and paleontology committee.
Mathematics committee.
Committee on navigation and nautical instruments.
Physics committee.
Psychology committee.
Committee on research in educational institutions.
Zoology committee.

Since the close of the year the Signal Corps, desiring to avail itself of the assistance of the National Research Council, appointed Dr. R. A. Millikan, third vice chairman and executive officer, and Dr. Charles E. Mendenhall majors in the United States Army.

PUBLICATIONS.

The Institution proper issues three series of publications: Smithsonian Contributions to Knowledge, Smithsonian Miscellaneous Collections, and Smithsonian Annual Reports. The publications of the various branches of the Institution issued under its direction include the Annual Reports, Proceedings, and Bulletins of the United States National Museum, including the Contributions from the National Herbarium; Annual Reports and Bulletins of the Bureau of American Ethnology; and the Annals of the Astrophysical Observatory. All of the publications of these branches and the Annual Report of the Institution are printed by means of congressional allotments.

Smithsonian Contributions to Knowledge.—Of this series, which contains in quarto form the results of studies constituting important contributions to knowledge, one memoir was published, entitled "A Contribution to the Comparative Histology of the Femur," by Dr. J. S. Foote, of Creighton Medical College, embodying the results of the author's work for a number of years on this subject.

Smithsonian Miscellaneous Collections.—Of this series, 19 papers forming parts of five volumes were issued, including three papers by your Secretary containing the results of his field work in Cambrian geology. The annual Smithsonian exploration pamphlet appears in this series, which describes briefly the work in the field of the Smithsonian scientists and scientific expeditions, illustrated by photographs taken by the explorers in every quarter of the globe. The necessity for a second reprinting of the sixth revised edition of the Smithsonian Physical Tables indicates the continued usefulness of this work. In this series also appeared the important paper by H. Helm Clayton on the effect of variations in solar radiation on the earth's atmosphere, the possibilities of which for use in forecasting temperature are discussed elsewhere in this report.

Smithsonian report.—As stated in the report on the publications, Appendix 8, although the final proof of the 1916 report was returned to the printer in April, the books were not received before the close of the year because of the great rush of war printing at the Government Printing Office.

Special publications.—Among the special publications may be mentioned an illustrated folder describing the Smithsonian and its branches, for the use of visitors and correspondents.

National Museum publications.—The Museum issued during the year 1 volume of the proceedings, 73 papers forming parts of this and other volumes, and 6 bulletins.

Bureau of Ethnology publications.—The Bureau of American Ethnology published 1 annual report, 2 bulletins, and a list of publications of the bureau.

Reports of historical and patriotic societies.—In accordance with a provision in the charters of the American Historical Association and the National Society of the Daughters of the American Revolution, the annual reports of those organizations were submitted to your Secretary, and communicated by him to Congress.

Allotments for printing.—The allotments for the printing of the Smithsonian report and the various publications of the branches of the Institution were practically used up, a small balance remaining in one or two cases owing to the impossibility of getting certain publications off the press before the close of the year.

The allotments for the year ending June 30, 1918, are as follows:

For the Smithsonian Institution: For printing and binding the annual reports of the Board of Regents, with general appendixes, the editions of which shall not exceed 10,000 copies	$10,000
For the annual reports of the National Museum, with general appendixes, and for printing labels and blanks, and for the bulletins and proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding, in half morocco or material not more expensive, scientific books, and pamphlets presented to or acquired by the National Museum library	37,500
For the annual reports and bulletins of the Bureau of American Ethnology and for miscellaneous printing and binding for the bureau	21,000
For miscellaneous printing and binding:	
International Exchanges	200
International Catalogue of Scientific Literature	100
National Zoological Park	200
Astrophysical Observatory	200
For the annual report of the American Historical Association	7,000
Total	76,200

Committee on printing and publication.—The Smithsonian advisory committee on printing and publication considers all manuscripts offered for publication by the Institution or its branches. During the past year 16 meetings were held, at which 101 manuscripts were considered and acted upon. The membership of the committee was as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, chairman; Dr. C. G. Abbot, director of the Astrophysical Observatory; Mr. Ned Hollister, superintendent of the National Zoological Park; Mr. A. Howard Clark, editor of the Institution, secretary of the committee; Mr. F. W. Hodge, ethnologist in charge of

the Bureau of American Ethnology; and Dr. George P. Merrill, head curator of geology, National Museum.

LIBRARY.

The main purpose of the library of the Smithsonian Institution has been to assemble a collection of periodicals and publications of a scientific nature as well as the journals and other publications of the scientific institutions and learned societies of the world, the whole to be a library of reference for research in the broadest sense. In carrying out this policy an accumulation of over half a million titles has been made, the main part of which is housed in the Library of Congress with the designation of the Smithsonian deposit of the Library of Congress. In addition to this main part of the Smithsonian library there are maintained a number of smaller libraries at the various branches of the Institution, the National Museum library, the Bureau of American Ethnology library, the Astrophysical Observatory library, and the National Zoological Park library. In the various offices of the Institution and the Museum sectional libraries of technical works in all branches of science are maintained for the use of the scientific staff. There are 35 of these sectional technical libraries.

The accessions to the libraries of the Institution and its branches during the year aggregated more than 9,000 volumes, parts of volumes, and pamphlets. Among important gifts during the year was a first consignment of 561 volumes and 293 pamphlets, part of the botanical library of Dr. John Donnell Smith, of Baltimore; the whole of which, amounting to 1,500 volumes, he has offered to the Institution.

In the Museum library, 1,672 volumes and 3,556 pamphlets were accessioned during the year, among them the scientific library of Dr. Edgar A. Mearns, associate in zoology, who died last fall. This collection is rich in works on mammals, birds, and plants. Through the continued generosity of Dr. William H. Dall, honorary curator of mollusks, the sectional library of the division of mollusks has been enriched by the addition of 307 titles during the year.

RECEPTION IN HONOR OF FRENCH SCIENTISTS.

On the evening of June 14, under the auspices of the National Academy of Sciences, a reception was held in the Smithsonian building for the members of the French Scientific Mission to the United States. Prof. Charles Fabry told of what France is doing in the war; Commander Bridge spoke of Great Britain's work in submarine warfare; and Sir Ernest Rutherford sketched the situation as England sees it. President Walcott, of the National Academy of Sciences,

and Mrs. Walcott were assisted by Lieut. Maurice Paternot, Prof. Charles Fabry, and Prof. Henri Abraham in receiving the guests.

NATIONAL MUSEUM.

One of the most important features to be recorded in the operations of the National Museum during the year was the actual beginning of the building for the Charles L. Freer Art Collections. Excavation was started on October 2, 1916, and by June 30, 1917, the foundations and concrete walls inclosing the subbasement had been complete. The structure, covering 228 by 185 feet, will be of Milford granite and in exterior and interior design best adapted to its purpose. Assistant Secretary Rathbun in the appendix to the present report gives some interesting details regarding this addition to the Smithsonian group of buildings. The construction of this art building is made possible through the most generous gift of $1,000,000 by Mr. Freer for the housing and study of the magnificent collection he has presented to the Nation. His gift of the building and collection is the most valued donation which any individual has ever made to the Government.

The accessions to the National Museum collections during the year aggregated about 200,000 specimens pertaining to anthropology, zoology, botany, geology and mineralogy, paleontology, textiles and woods, mineral technology, and objects of art. In his report Assistant Secretary Rathbun enumerates the sources and importance of these accessions, so that it is not necessary here to do more than to mention some of the principal items. Interesting collections of anthropological objects were received from the island of Celebes, gathered at the expense of Dr. W. L. Abbott, who for many years has most generously contributed toward the growth of the Museum in ethnological and biological material from various parts of the world. Doctor Abbott personally visited the West Indies during the year and met with gratifying success in adding to our knowledge of the early history of man and of the fauna of that region. A large collection of stone implements belonging to the ancient town builders of Mexico was received through Captains Wright and Cooper of General Pershing's expedition, and extensive archeological collections from the Southwestern States were gathered by Doctor Fewkes and others connected with the Bureau of American Ethnology. Hundreds of objects of great value in the study of physical anthropology came to the museum as the result of explorations by Doctor Hrdlička and others in Peru.

To the division of American history memorials were added pertaining to eminent military and naval men and other prominent Americans and objects commemorative of historic events, besides

costumes, furniture, and other articles illustrative of colonial and later periods.

Although the Museum is without funds for carrying on extended biological explorations, yet through the generosity of friends it has been greatly enriched by the results of field work in various parts of the world, particularly the work of Dr. W. L. Abbott so often mentioned heretofore. A large and fine collection of reptiles and batrachians came as a bequest by the late Julius Hurter, sr., of St. Louis.

To the botanical collections were added about 25,000 specimens and the remnant of the botanical library saved from the flood which so nearly destroyed the Vanderbilt Herbarium at Biltmore, N. C., in July, 1916. These objects were presented by Mrs. Vanderbilt. Prof. O. F. Cook gave to the Museum about 15,000 specimens of cryptogams gathered in the United States and Liberia.

In geological material, likewise, and in the department of textiles, mineral technology, and other divisions of the Museum, there were important additions described by the assistant secretary.

The attendance of visitors to the Natural History building aggregated about 400,000 and the Arts and Industries building about 250,000.

In calling attention to the present needs of the Museum, I may mention the fact that on account of the great growth of the collections during the last few years there is already presented a lack of exhibition and storage facilities in some of the departments, particularly in connection with the applied arts, the fine arts, and American history. It is exceedingly gratifying that the accessions should increase in such great proportions from year to year, but it is likewise important that there be a corresponding increase in the number of the scientific staff and other employees necessary for the proper care and study of this mass of material made up in great measure through gifts by the people of the Nation.

BUREAU OF AMERICAN ETHNOLOGY.

The Bureau of American Ethnology, which conducts ethnological researches among the American Indians and the natives of Hawaii, is under the direction of Mr. F. W. Hodge, whose report is given in Appendix 2.

Among the important researches of the year was the excavation and study of Hawikuh, a large reservation on the Zuñi Reservation in western New Mexico. This work was carried on by Mr. Hodge in cooperation with the Museum of the American Indian, Heye Foundation, of New York City. The purpose of the excavation of Hawikuh was to study a Zuñi pueblo, known to have been

inhabited from prehistoric times well into the historic period, to determine as far as possible the character and arts of the Zuñi people in early times, as well as the effect of Spanish contact during the sixteenth and seventeenth centuries. The results of this important study, which were highly successful, will be published in the near future.

In the Mesa Verde National Park Dr. J. Walter Fewkes excavated and repaired a large rectangular ruin, 100 by 113 feet, to which he gave the name of Far View House, by reason of its commanding situation on the mesa. The most important result of the study of this structure is the revelation of a new type of Mesa Verde building, the form and character of which throw light on the close relation of pueblos and cliff dwellings. Dr. Fewkes believes that this structure is the only example of a pure type of pueblo ever completely excavated, the term "pure type" meaning a terraced community building constructed of shaped stones and having circular kivas, or ceremonial rooms, united with surrounding rectangular rooms. This type of pueblo may be considered a stage in architectural development between the older type of structure and the mixed or modern form which shows a retrogression in the art of masonry.

Mr. J. N. B. Hewitt, while conducting studies in Canada relative to the Iroquois League, was selected as an official delegate from the council of the Six Nations to attend a condolence and installation ceremony at Munciefown, in which he took a leading part, requiring the intoning of an address of comforting in the Onondaga language and also in acting the part of the Seneca chiefs in such a council.

Among the special researches carried on during the year may be mentioned the completion of the manuscript on the ethnology of the Kwakiutl Indians by Dr. Franz Boas, honorary philologist. Work is nearly completed on the results of the field work on the Salishan language, carried on through the generosity of Mr. Homer E. Sargent, of Chicago, by Mr. James Teit. The study of Indian music has been continued by Miss Frances Densmore, sufficient data now being on hand to complete a work on the music of the Ute Indians, among whom Miss Densmore has now spent two field seasons.

The bureau has published during the year 1 annual report, 2 bulletins, and a list of publications of the bureau. In press or in preparation at the close of the year were 4 reports and 8 bulletins. The library of the bureau accessioned 435 new books and 388 pamphlets.

INTERNATIONAL EXCHANGES.

The International Exchange Service, for the exchange of governmental and scientific publications with other countries, though very much hampered in its operations by war conditions, has nevertheless

handled during the year a total of 268,025 packages, weighing 290,103 pounds. On account of the very high ocean freight rates Congress allowed a small additional appropriation to meet the expense of foreign shipments.

Suspension of shipments is still found to be necessary in the case of about 10 countries. It is gratifying to note that since the beginning of the war only three shipments sent out by the Institution have been lost through hostile action, two of these being on vessels sunk by hostile warships. Wherever possible duplicate copies of the publications in lost consignments are procured and another shipment made.

It has been the custom of the Government of India to refer requests from establishments in this country for Indian official documents to the Exchange Service for indorsement, and this year a request for similar services by the director of the Government press at Cairo, Egypt, has been granted.

NATIONAL ZOOLOGICAL PARK.

The National Zoological Park is each year becoming more and more recognized as a means of natural history education and as a place of recreation and amusement for the public, and the collection of animals is now one of the most varied and interesting of its kind in the country.

In October, 1916, Dr. Frank Baker, superintendent of the park for 26 years, resigned to take effect November 1, and was succeeded by Mr. Ned Hollister, assistant curator of the division of mammals in the National Museum.

The total number of animals in the park at the close of the fiscal year was 1,223, including 484 mammals, 683 birds, and 56 reptiles. Among important additions may be mentioned five adult Rocky Mountain sheep received from the Canadian Government; four Bedford deer or Manchurian stags, from the Duke of Bedford; and some desirable Australian marsupials presented by Mr. Victor J. Evans, of Washington, District of Columbia.

Visitors to the park during the year numbered 1,100,800, a daily average of 3,032. One hundred and fifty-three schools and classes examined the collection for educational purposes.

Among recent improvements the superintendent notes that the hospital and laboratory, on which work has been in progress for the past two years, now lacks only the laboratory equipment for the use of pathologists and the outside yards for the animals to be confined in the hospital limits. The lake for North American water fowl has been enlarged and reconstructed to show as many as possible of these birds in their natural surroundings. At present no

less than 136 American water birds of 24 species are to be seen in the lake.

Every effort is being made to make the park a sanctuary for native wild birds. Over 100 nesting boxes have been put in place and during the cold weather food is provided, resulting in a notable increase in the bird population of the park.

As noted in last year's report, the appropriation made by Congress in 1913 for the acquisition of a frontage for the park on Connecticut Avenue, lapsed owing to delays caused by legal complications, and it is regretted that Congress has not made a new appropriation for this purpose. As the principal entrance to the park will probably be on Connecticut Avenue for all time, it is exceedingly important that the land in question be acquired before it is too late.

Among the imperative needs of the park, the superintendent mentions some provision for the parking of the increasing number of automobiles that visit the Zoo, outdoor dens for carnivorous animals, additional ponds for waterfowl, a bird house, and a reptile house. The most urgent need, however, is a substantial increase in the general appropriation. Owing to the steady advance in the cost of supplies and the increasing expense occasioned by the larger number of visitors, the point has now been reached where the entire appropriation, which has remained the same for the past seven years, does not cover actual maintenance expenses.

For some years past the National Zoological Park, in common with other similar institutions in the United States, has felt the effect of conditions that operated to hinder more and more the importation of wild animals from abroad and to reduce the supply.

At the suggestion of Dr. W. T. Hornaday, director of the New York Zoological Park, a conference was held at the Philadelphia Zoological Garden to consider the question of sending a joint expedition, on behalf of the New York, Philadelphia, and National Zoological Parks, to South Africa for animals. It was decided to send a man out to look the ground over, see what could be done in the way of arranging for a supply of animals for the future, and bring back anything desirable that could be secured at the time. Mr. J. Alden Loring, who had been successful in bringing animals from Europe for the New York Zoological Park, and had also had experience in Africa as a member of the Smithsonian expedition to East Africa, was selected to make the trip.

Mr. Loring sailed from New York July 22, 1916, taking with him hay and grain enough to feed as many antelopes and other herbivora as he was likely to obtain, for one of the conditions necessary to secure their entry into the United States was that no forage from Africa should be brought with the animals. He arrived at Port

Elizabeth, South Africa, August 31, and, returning, sailed from Durban November 22.

The opportunities for securing animals to bring back were found to be in some respects less favorable than had been anticipated, but fortunately the zoological garden at Pretoria was fairly well stocked, and the director was kind enough to deplete the collection somewhat for the benefit of his distant colleagues. Most of the animals which Mr. Loring brought back were obtained there, an interesting collection of mammals and birds being secured. The mammals obtained include a gemsbuck, a blessbuck, a white-tailed gnu, a nilgai, four springbucks, a pair of duikers, a pair of meerkats, and a few monkeys and rodents. Among the birds are two secretary vultures, a bateleur eagle, a hornbill, francolins of several species, a few touracous and hawks, and a number of smaller birds. The collection has been divided between the three institutions concerned, according to their choice, and in proportion to the share of the expenses that was borne by each. Altogether there were secured 28 mammals, representing 13 species; 60 birds, of 25 species; and 55 snakes and tortoises, of 8 species.

While in South Africa Mr. Loring visited and made notes on the zoological gardens at Cape Town, Durban, Bloemfontein, Johannesburg, and Pretoria.

ASTROPHYSICAL OBSERVATORY.

Measurements of solar radiation were continued as usual on Mount Wilson. As stated in connection with the Hodgkins fund, an allotment has been made to undertake similar work in South America. Much attention was devoted by Director Abbot to the preparation of the equipment of this expedition. Valuable new instruments were devised and constructed under his direction. Owing to war conditions the expedition was located temporarily at Hump Mountain, North Carolina, in May, 1917, and shelters prepared and apparatus set up and adjusted under the care of Messrs. Abbot and Aldrich. The research on the absorption of terrestrial radiation by vapors of the atmosphere, upon which Mr. Fowle has been engaged for several years, has been completed, and the results, which are of great importance to meteorology, have been made ready for publication by the Institution. A paper of uncommon interest by H. Helm Clayton, based upon observations by the Astrophysical Observatory, has been published in the Smithsonian Miscellaneous Collections. The author shows that the short-interval solar variations, discovered in Mount Wilson work, affect terrestrial temperatures and pressures the world over in a well-marked and predictable manner. It is greatly to be hoped that daily solar-radiation obser-

vations at all times of the year may be obtained for use in such meteorological researches. It was for this purpose that the South American expedition was planned, and it will be unfortunate, indeed, if war conditions should long delay the carrying out of this work.

POSSIBILITY OF FORECASTING FROM SOLAR OBSERVATIONS.

As Doctor Clayton has shown that variations of the sun are followed a day or two later by correlated variations of temperature, it is of interest to inquire if the fluctuations of temperature thus caused are large enough to be worth predicting. From Clayton's curves it seems to be shown that in 1913 and 1914 changes of solar radiation of 1 per cent produced changes of maximum temperatures as follows:

Pilar, Argentina.	+5.2° C.
Manila, Philippine Islands.	+1.5° C.
Winnipeg, Canada.	−6.3° C.

It may be supposed that the mean temperatures changed half as much, or +2.6°, +0.75°, and −3.15° corresponding to 1 per cent rise of solar radiation. Changes of 3 per cent or even 5 per cent in solar radiation within 10 days are not very uncommon. For instance note the following values of "solar constant" observed on Mount Wilson in 1911:

Date, Sept.	3	4	5	6	7	8	9	10	11
Value	1.888	1.908	1.917	1.960	1.938	1.993	1.948	1.908	1.892

The observed range was 5.5 per cent in 8 days.

Obviously, the subject presents possibilities that when sufficient observing stations are equipped in various cloudless regions to yield accurate "solar constant" values every day, it may be possible to forecast for one or two days in advance a very considerable part of the now outstanding temperature fluctuations. At present the two stations of the Smithsonian Institution in California and North Carolina are the only ones making the required solar observations, and not in half of the days in the year, especially in midwinter and midsummer, can observations be made on account of cloudiness. A bequest of $500,000 would enable the Institution to equip and maintain indefinitely the required observing stations.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

As the greater part of the countries supporting regional bureaus of the International Catalogue of Scientific Literature are now actually engaged in hostilities, a great deal of difficulty has been encoun-

tered in preparing and financing the Catalogue. The number of scientific papers being published has greatly decreased and it has been found practically impossible to obtain the necessary scientific and clerical assistance for the preparation of the Catalogue. However, the Central Bureau at London has succeeded in issuing four volumes, the twelfth annual issue of geology, and the thirteenth annual issue of chemistry, anatomy, and botany. This brings the total number of volumes published since the inception of the Catalogue in 1901, up to 216 volumes containing about 3,000,000 references to current scientific periodicals. The organization as a whole is holding together very well under extremely adverse conditions, and when peace is declared it will be necessary only to resume, rather than reorganize the work.

It is becoming more and more difficult to draw the line between pure science and applied science, and the present limitation of the Catalogue to pure science should be broadened to include at least some of the applied sciences which are advancing with such great strides. Although this would increase the size and cost of the Catalogue, yet its enhanced value would by increasing the demand for it and consequently its sale, offset any additional cost.

Respectfully submitted.

Charles D. Walcott, *Secretary.*

Appendix 1.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

Sir: I have the honor to submit the following report on the operations of the United States National Museum for the fiscal year ending June 30, 1917:

INTRODUCTORY.

In the last report it was stated that Mr. Charles L. Freer had made arrangements for the immediate erection of the building to house the valuable collections of American and oriental art which he has presented to the Nation through the Smithsonian Institution, and also that the preliminary plans had been approved, the site selected and the necessary funds, amounting to $1,000,000, transmitted by him to the Institution. It is exceedingly gratifying to announce that the detailed plans having been sufficiently advanced by that time the work of excavating was begun on October 2, 1916, and by the close of the fiscal year the foundations, including the concrete walls inclosing the subbasement, had been completed.

This addition to the Smithsonian group of buildings, with a frontage of 228 feet, a depth of 185 feet, and a height of 46 feet, and containing an open central court about 65 feet square, will present an exterior of pink granite from quarries at Milford, Massachusetts, a stone which has been employed with good effect for several prominent structures in Washington. Above the ground level it will consist only of a basement and main story, the former lighted by windows, the latter almost wholly by skylights, leaving the upper part of the walls essentially unpierced except for the entrances, of which that on the north front comprises three large arched openings. The location, at the corner of Twelfth and B streets SW., between the buildings of the Smithsonian Institution and the Department of Agriculture, seems to assure favorable surroundings for the future, as there is slight probability of intrusion by any high or otherwise objectionable constructions in that vicinity.

Not only beautiful and effective in general design, but showing in interior plan a thorough adaptation to the requirements of the collections both as to space and to lighting, with such facilities as will make it practically an independent unit of the Smithsonian

group, the character of the construction work so far as it has been carried leaves nothing to be desired in respect either to enduring quality or to interpretation of the architect's conception.

The subbasement will contain the appliances connected with the heating, lighting, and ventilation of the building, but steam and electric current will be supplied from the central plant of the Museum. In the basement, which will be a well-lighted story, will be located large studios and rooms for the storage of such parts of the collections as are not on exhibition, a capacious lecture hall, an office for the curator, and work and comfort rooms, furnishing, in fact, all necessary conveniences for administration, for serious study, and for popular instruction.

The main story will be entirely devoted to exhibition purposes and be divided into 19 rooms, each designed for a particular subject or class of objects, reached by wide corridors. The Whistler collection will occupy 5 of these rooms, in one of which the decorations of the famous peacock room will be installed. The central court, to contain a fountain, will be a special feature of this story, large, arched openings lighting the adjoining corridors and loggias. The entire available floor space of the main and basement stories will aggregate some 55,000 square feet, about equally divided between the two floors.

It will be recalled that this building is designed to accommodate only the Freer collections and to provide for the study and appreciation of their varied contents which supply a vast amount of material for research work by specialists. As an integral part of this specific gift of art, the most important and valued donation which any individual has ever made, freely and unconditionally, to the Nation, it can not be otherwise employed. Its completion, an event anticipated for the fiscal year 1918–19, while insuring an incalculable gain for the Museum and the public, will not, therefore, satisfy any of the needs, set forth in the last report, in respect to additional space for the national collections of both the applied and the fine arts, as also of American history. The valuable materials in these departments, which have long since been seriously overcrowded, can at present be neither properly utilized nor appropriately brought to the attention of the public. In one branch especially, that of the industrial arts, it is unfortunate that such a condition should now exist, particularly as it is coupled with lack of means for securing an adequate staff of practical experts, as the collections are closely associated with many of the vital problems now confronting the country. With its limited facilities, however, an effort is being made to demonstrate the value of Museum work in time of crisis, and contributions made since the close of the year but in time to mention

the fact of their publication here, have been recognized as of great national importance by those high in authority.

COLLECTIONS.

The additions to the collections, received in 1,450 accessions, aggregated approximately 195,845 specimens and articles, classified by subjects as follows: Anthropology, 10,775; zoology, 71,761; botany, 79,155; geology and mineralogy, 9,800; paleontology, 23,190; textiles and woods, 933; mineral technology, 213; and National Gallery of Art, 18. Many loans were also accepted for exhibition, chiefly in the Gallery of Art and the division of American history; and 906 lots of material, consisting mainly of rocks, ores, minerals, and zoological specimens were received from various parts of the country for examination and report.

Anthropology.—A varied collection from the island of Celebes, made by Mr. H. C. Raven and presented by Dr. W. L. Abbott, and a large number of objects exhibiting every phase of the textile art as practiced among the Indians of British Guiana, assembled by Dr. Walter Roth, constituted the most important accessions in ethnology. Pertaining to aborigines of the North American Continent were rare Papago Indian baskets, baskets of interesting weaves and designs, carved and painted house posts, etc., from the Quileute Indians of Washington; articles of ivory, horn, wood, bark, and stone from Eskimo and British Columbian tribes; and many objects pertaining to the Pueblo Indians of Arizona and New Mexico. Other acquisitions were from Mexico, Central America, Abyssinia, Japan, China, and the Philippines.

Especially noteworthy was a large collection of antiquities made by Capts. John W. Wright and Alexander T. Cooper, United States Army, while with General Pershing's expedition in the State of Chihuahua, Mexico, comprising nearly every variety of artifact of stone belonging to the ancient mound builders of that region.

Explorations under the Smithsonian Institution resulted in extensive archeological collections from the Mesa Verde National Park, Colorado, and from old Zuñi ruins near Gallup, New Mexico, made by Dr. J. Walter Fewkes; from ancient pit villages in New Mexico and ruins at Awatobi, Arizona, made by Dr. Walter Hough; from sites of prehistoric adobe dwellings in western Utah, made by Mr. Neil M. Judd; and from a cave in the southern wall of Cibollita Valley, New Mexico, made by Mr. F. W. Hodge. Dr. W. L. Abbott presented much valuable archeological material obtained during his investigations in Santo Domingo, and among the smaller accessions were many rare specimens from North and Central America.

Hadji Ephraim and Mr. Mordecai Benguiat made important additions to the rich collection of antique Jewish objects lent by them during previous years. Included in a valuable gift from the estate of the late John Chandler Bancroft Davis were necklaces, scarabs, figurines, and Ptolemaic coins from Egypt, a sculptured brick from the Colosseum at Rome, and marble and terra-cotta vases. From Miss Isobel H. Lenman were received as a loan a collection of ancient glassware, comprising bottles, flasks, bowls, cups, tear bottles, bracelets, beads, and other articles, displaying the marvelous irridescence characteristic of the ancient glassware of Syria and Phoenicia.

The principal accession in physical anthropology consisted of material obtained in Peru by Dr. Aleš Hrdlička in 1915 in connection with the assembling of exhibits for the Panama-California Exposition. It includes hundreds of objects of great value, among which are many specimens representing rare and in some instances unique anatomical features. Besides an excellent series of brains of gorillas and chimpanzees from the Cameroons and casts of the Sivapithecus remains from India, aboriginal skulls and other bones were received from the vicinity of Vero and Fort Myers, Florida, representing the supposedly very ancient man of that region, from ancient mounds in Utah and the Mesa Verde ruins in Colorado, from Tennessee and Illinois, and from Colombia and Hawaii.

Among the many acquisitions in the division of mechanical technology were rare watch movements; early pieces of apparatus relating to the invention and history of the telegraph, the telephone, the telautograph, the phonograph, and the graphophone; a Howe sewing machine, which sewed the first seam done by machinery; and numerous interesting firearms, some of early make.

To his previous munificent donation, illustrating the history and development of the pianoforte and including dulcimers, spinets, clavichords, harpsichords, and organs, Mr. Hugo Worch added 28 pieces, increasing the extent of this remarkable collection to 117 instruments.

An instructive addition to the exhibition series in graphic arts was a life-size figure of a Japanese wood-cut printer at work, the outfit, complete in every detail, having been a gift from the Imperial Government of Japan. A much earlier stage in the development of graphic methods is illustrated by an original Mexican painting, executed on a sheet of palmetto fiber smoothly surfaced with white clay. Among other interesting acquisitions were one of the earliest forms of the machine for casting linotype slugs; materials of the various kinds employed in miniature painting, with examples of miniature work on ivory, parchment, and porcelain; and a series of specimens illustrating processes in making line-cut and halftone engraving.

American history.—The most notable memorial accession consisted of a large number of relics of Admiral David G. Farragut, United States Navy, including a jeweled sword presented by the Union League Club of New York and a portrait of Farragut by William Swain, which were received as a donation from the estate of the late Loyall Farragut, only son of the Admiral. Other officers of the Navy represented by contributions were Commodore Stephen Decatur, Commodore John Rodgers, and Rear Admiral C. M. Chester. Among the furniture secured for the collection were pieces which had belonged to Presidents Washington and Jefferson, President and Mrs. Madison, and Charles Cotesworth Pinckney, American minister to France in 1796–1798. To the large series of medals awarded Commander Matthew Fontaine Maury in recognition of his services to science, and placed in the Museum by several of his descendants, was added the ribbon of the Grand Cross of the Order of Our Lady of Guadaloupe, presented by Emperor Maximilian of Mexico in 1866, a gift from Mrs. Mary Maury Werth.

For the gift of the wedding dress of Harriet Lane Johnston, niece of President Buchanan, for several years shown in the section of historical costumes, the Museum was indebted to Miss May S. Kennedy. Other hostesses of the White House represented by costumes more or less complete, lent during the year for incorporation in the central feature of the hall, were Mrs. Martha Jefferson Randolph, daughter of President Jefferson; Mrs. Martha Johnson Patterson, daughter of President Johnson; and Mrs. Theodore Roosevelt. Among interesting relics were a silk dressing gown of Lafayette, an eiderdown quilt used by Jefferson, a beaded bag of Mrs. James Monroe, and a handkerchief that had belonged to Queen Anne.

A large number of decorations, medals, and badges of the United States and foreign countries, which had been assembled by the late Lieut. Thomas Kelly Boggs and were presented by Mrs. Boggs, formed a very gratifying addition to the numismatic collection. The greater part of these tokens are foreign war decorations of very timely interest, and 23 countries are represented. The philatelic collection was augmented to the extent of 3,398 specimens, mainly received through the Post Office Department, and including 1,893 examples of new issues of stamps from countries in the Universal Postal Union.

Biology.—Through the generosity of friends the department of biology was greatly enriched by the results of field work in different parts of the world, adding new genera and species and many forms not previously represented in the Museum. Mr. H. C. Raven, under a further grant of funds by Dr. W. L. Abbott, continued his collecting on the island of Celebes, sending to Washington about 900 mammal skins, besides over 1,000 specimens each of birds and mollusks.

Doctor Abbott personally spent some time in Haiti, where he obtained many birds, including species whose occurrence on that island was unexpected, reptiles, and mollusks, and also a large quantity of bones of mammals from prehistoric kitchenmiddens. The study of similar deposits on this and other islands of the Antilles was an interesting feature of the year's activities, a large collection of bones gathered by Mr. Theodoor de Booy in Cuba, Santo Domingo, and the Virgin Islands, and presented by Mr. George G. Heye, having yielded new genera of rodents, birds, and reptiles, which have apparently become extinct within comparatively recent times.

As the proceeds of an expedition to Cuba and Haiti by Mr. John B. Henderson, accompanied by Dr. Paul Bartsch, the Museum received from Mr. Henderson numerous birds, reptiles, and fishes, and over 15,000 land and marine invertebrates, mostly mollusks. Mr. F. J. Dyer, American consul at Ceiba, Honduras, contributed a large number of insects and mollusks from that country; and Mr. Arthur de C. Sowerby transmitted mammals, birds, crustaceans, and mollusks from northern China and Manchuria.

The Bureau of Fisheries deposited, as usual, valuable collections of fishes and marine invertebrates, besides many interesting specimens of mammals, birds, and reptiles. Among the fishes were 72 types, cotypes, and paratypes, 40 of which were of species obtained on the Philippine cruise of the steamer *Albatross* in 1907–1911. The marine invertebrates, numbering several thousand specimens, included recently described type collections of annelids and parasitic copepods. Transfers, chiefly of mollusks and crustaceans, aggregating over 400 specimens, were made by the Biological Survey and Bureaus of Entomology and Plant Industry of the Department of Agriculture.

Exceptionally noteworthy was a bequest to the Museum by the late Julius Hurter, sr., of St. Louis. An enthusiastic collector, he had gathered one of the largest and finest private collections of reptiles and batrachians in existence. Its principal scientific value lies in its splendid series of Missouri forms which served as the basis for Mr. Hurter's "Herpetology of Missouri," published in 1911. Not solely confined to that region, however, it contains valuable material from various parts of the world, and most of the important subdivisions of the group are represented.

From the Santa Marta Mountains in Colombia were received 149 specimens of birds, which added 6 species new to the Museum, and from Panama, 213 specimens of reptiles and batrachians, the latter collected by the Smithsonian biological survey of the Canal Zone. Mr. James Zetek transmitted 709 specimens of mollusks and other marine invertebrates from Panama, and Prof. G. S. Dodds, of the University of Missouri, presented a large number of Entomostraca,

representing 55 species, collected in 124 lakes and ponds in Colorado and forming the basis of a paper which he had published.

The Bureau of Entomology was the principal contributor of insects, transferring about 3,000 specimens of various orders. The material from American Consul Dyer in Honduras has already been mentioned. The other more important accessions comprised Lepidoptera from Peru, Mexico, and Alaska; Hymenoptera from western Argentina, and a collection of miscellaneous insects from Mount Kinabalu, British North Borneo.

The additions to the botanical collections exceeded 79,000 specimens, including about 25,000 specimens from the Vanderbilt Herbarium at Biltmore, North Carolina, comprising all that were saved from the disastrous flood of July 15–16, 1916. This valuable herbarium, which was established and maintained for many years by the late George W. Vanderbilt, contained at the time of the flood upward of 100,000 specimens, and was especially noteworthy for its representation of the plants of the southeastern United States. This accession, which was accompanied by the remnant of the botanical library attached to the herbarium, was a gift from Mrs. Vanderbilt.

Another notable accession consisted of about 15,000 specimens of cryptogams, mainly mosses, hepatics, fungi, and myxomycetes, from the northeastern United States and Liberia, presented by Prof. O. F. Cook. The Department of Agriculture deposited over 5,600 specimens, resulting principally from field work of the Bureau of Plant Industry and including many tropical American palms and Alaskan and Hawaiian plants. Through exchanges, important collections were obtained from the New York Botanical Garden, the Gray Herbarium of Harvard University, the Missouri Botanical Garden, the British Museum, and the Bureau of Science at Manila. A gift of about 1,000 Venezuelan plants was received from the Carnegie Institution of Washington, and about 5,000 specimens were collected in New Mexico for the Museum by Mr. Paul C. Standley, assistant curator.

Geology.—The Charles U. Shepard collection of meteorites, the bequest of which was announced in the last report, was formally transferred to the Museum during the year, and constitutes one of the most important accessions ever acquired by the department of geology. It comprises 248 falls and finds. Additional specimens of meteorites to the number of 26 were obtained by gift and exchange, and there were many acquisitions of valuable ores and rocks from various localities.

The more prominent accessions of minerals, as also of petrological material, were from the Geological Survey. Among the former, were a fine large series illustrating the occurrence of turquoise, a

number of amethyst crystals, many semiprecious stones, and a large number of minerals and rocks collected in connection with studies of the gem deposits of southern California. Among the latter were extensive collections of rocks and ores representing geological researches in several districts in the western United States.

From other sources were obtained many rare as well as some instructive series of minerals and a number of showy specimens especially desired for exhibition. Among these were type specimens of stevensite and creedite, material illustrating the genesis of the zeolites and their association with glauberite cavities, a remarkable specimen of glendonite from Australia, an exceptionally large crystal of iron pyrite and a fine specimen of crystallized anglesite.

The principal acquisitions in invertebrate paleontology were a collection of Silurian fossils, transferred by the Geological Survey, which had formed the basis of papers illustrating the geology and paleontology of Maine, the types of nine species of Paleozoic crinoids, a series of rare and recently described insects from the Tertiary rocks of Colorado, several hundred species of European invertebrates, and about 2,000 specimens of Lower Ordovician fossils from the zinc mines of Arkansas.

A collection of Permian vertebrates from Baylor County, Texas, contains the greater part of a skeleton of the large finbacked reptile *Dimetrodon*, complete enough to mount for exhibition, besides remains in less perfect condition of the same form and of *Cardiocephalus*, *Lysorophus*, *Diplocaulus*, *Seymouria*, and *Labidosaurus*, and many bones of small reptiles and batrachians. The skull and lower jaw of a fossil horse, the type of a recently described species, from the Pleistocene gravels of the Yukon Territory, and part of the skull of a fossil muskox from the Pleistocene of Miami County, Indiana, were also obtained.

About 400 specimens of small mammalian remains of rare forms from cave deposits in the mountains of western Cuba were collected for the Museum by Mr. William Palmer, and a large part of the skeleton of an extinct and probably undescribed species of bird was received from the Geological Survey. Goucher College, of Baltimore, deposited a collection of reptiles and cetacean remains from the Arundel formation of Maryland, bringing together in the National Museum practically all of the known vertebrate material from that formation in Maryland.

Secretary Walcott and party spent the summer and early fall on the Continental Divide between Alberta and British Columbia, south of the Canadian Pacific Railway, and besides extensive geological observations collected about 1,000 pounds of Cambrian material containing fossils, which were shipped to Washington.

Textiles.—The accessions in the division of textiles comprised many excellent examples of the present-day productions of American textile industries. The largest group of specimens received consisted of the most important types of cotton threads, arranged to show the various ways in which they are wound and put up for family and factory use. They were accompanied by several beautiful examples of tatting, crochet, embroidery, and cut work, in white and colors, suggesting artistic and practical uses for many of the threads in the series, and supplemented an extensive series of models and machine parts illustrating the manufacture of cotton thread previously received from the same contributor.

The hearty cooperation of many American manufacturers has continued to keep the collections supplied with new types and designs of dress goods as soon as these novelties appear on the market. The exhibits illustrating the principal methods used in decorating fabrics were enriched by numerous examples of tied and dyed work and many samples of skein-dyed plaid silks for comparison with piece-dyed and printed fabrics.

Fresh samples of the standard types of ribbons commonly used and many beautiful specimens of novelty and fancy ribbons, showing Aztec, Indian, Chinese, and Byzantine designs, augmented the ribbon section. The adaptability of mohair, by reason of its luster and resiliency, to the manufacture of plushes, velvets, and fur fabrics was shown in an instructive series of specimens comprising upholstery goods, cloakings, trimmings, and automobile rugs. Examples of household industry in the textile arts of a former period were received in the form of hand-woven coverlets and quilts, while valuable specimens of foreign hand-worked textiles from China, Spain, and Germany were added to the collection through friends of the Museum.

Additions were obtained for the collection of implements illustrating the preparation and use of flax and other fibers in former times, including an old wooden rope machine which had seen many years' service in twisting bed cords and wash lines. The utilization of pine needles in the manufacture of coiled baskets and of split-palm stems for large pack baskets was shown in other accessions.

Wood technology.—Although circumstances greatly retarded the progress of work in wood technology, some interesting exhibits were secured. A model measuring 12 by 15 feet and contributed by the Forest Service is designed to show the various important uses of the national forests and their administration. A comprehensive cork exhibit covers every phase of the industry from the raw bark to the many articles made from this substance, and certain modern methods of preserving wood are represented by a model and samples of the materials employed. Examples of 15 species of Argentine woods

and 49 specimens of wood from Surinam were added to the commercial series of timbers, and the series illustrating wood finishing and tanning materials were also increased.

Mineral technology.—Most important among the additions in mineral technology was an impressive model of the Bingham Canyon copper property in Utah, measuring 16 by 19 feet, accurately sculptured and colored, representing what is probably the most significant mining achievement of the present generation. It was a gift from the Utah Copper Co. The manufacture of white lead is shown in another excellent model presented by the National Lead Co., of New York, while among the models made in the Museum are five visualizing the mode of occurrence, the recovery, and the preparation, respectively, of tin, sulphur, asphalt, lime, and oil. A specimen exhibit illustrative of design and execution in cut glassware, specially prepared for the Museum, was contributed by T. G. Hawkes & Co., of Corning, New York, and another series of specimens exemplifying the properties and uses of asphalt came from the Barber Asphalt Paving Co.

Exhibits more or less representative or at least covering some phase of 18 mineral resource types are now available to the public in the halls of the division. Of these, abrasives, asbestos, asphalt, coal and coal products, copper, graphite, lime, mica, petroleum, plaster, Portland cement, and sulphur have been treated with sufficient fullness to warrant the publication of descriptive accounts of them and of their significance.

NATIONAL GALLERY OF ART.

The progress of work in the erection of the building for the Freer collections has already been mentioned. Next in importance to record in this connection are the terms of the will of Henry W. Ranger, N. A., one of the best-known of contemporary American painters, who died on November 7, 1916, leaving his residuary estate, estimated at over $200,000, to the National Academy of Design to be held as a permanent fund of which the income is to be used for purchasing paintings by American artists, the paintings so obtained to be given to art or other institutions in America which maintain a gallery open to the public, upon the express condition that the National Gallery of Art shall have the option and right to take, reclaim, and own any picture for its collection provided such option and right is exercised at any time during the five-year period beginning 10 years after the artist's death and ending 15 years after his death.

This generous provision by Mr. Ranger, which has been most gratifying to all lovers of art in this country and may be expected to have a stimulating influence upon the work of American artists,

will result in a much wider circulation than hitherto of good American paintings and insure the gradual assembling for perpetual exhibition at Washington of some of the best that our painters can produce. The system of selection will, in its working, be not unlike that which has been followed by the French Government in Paris, and it is to be hoped that the fund for so worthy a purpose may in time be greatly increased through corresponding action by other public benefactors. The National Gallery contains five of Mr. Ranger's paintings, all of which were presented by Mr. William T. Evans.

Among the permanent acquisitions by the Gallery during the year were the following oil paintings: "June," by John W. Alexander; "On the Lagoon, Venice," by R. Swain Gifford; "Portrait of Benjamin West," by himself; "Portrait of J. J. Shannon, R. A.," by Orlando Rouland; "The Song of the Sea," by William F. Halsall; "Portrait of Ellwood Hendrick," by Augustus Vincent Tack; "Evening," by William J. Kaula; "Landscape," by Chauncey F. Ryder; "A Breton Sunday," by Eugene Vail; "The Happy Mother," by Max Bohm; "Portrait of Maj. Gen. Julius Stahel, U. S. Volunteers," by J. Mortimer Lichtenauer; and "Portrait of Joseph Henry," first Secretary of the Smithsonian Institution, by Henry Ulke. Among the sculptures were a bronze "Statue of Robert Emmet," by Jerome Connor; a bronze figure, "The Fire Dance," by Louis Potter; and a marble statue "The Dying Tecumseh," by Chevalier Ferdinand Pettrich.

An oil portrait of Dr. Charles D. Walcott, recently painted by Ossip Perelma, was deposited by the Smithsonian Institution, as were also large oil portraits of Washington, Jackson, Henry Clay, and W. W. Corcoran, by the Supreme Court of the District of Columbia.

Through the kindness of Mr. Ralph Cross Johnson, many fine examples from his splendid private collection of paintings were continued on exhibition throughout the year, while the collection of Mr. W. A. Slater remained in the Gallery until in December. Seventeen paintings from 11 friends of the Gallery were also added to the general loan collection.

The Gallery held four special loan exhibitions during the year. The most notable of these, given under the auspices of the National Park Service of the Department of the Interior during January and February, and designed to bring to the attention of American tourists some of the marvelous natural attractions of their own country, consisted of 45 oil paintings illustrating scenes mainly in the National Parks and Monuments of the United States, among the 27 artists represented being Albert Bierstadt and Thomas Moran. Assembled in connection with the meeting of the National Parks

Conference held in the Museum auditorium from January 2 to 6, this interesting exhibition was opened with a special view on the evening of the second and the majority of the paintings remained on display until March. It was supplemented by series of photographs, studies in oil, and other pictorial matter shown in several rooms.

The other special exhibitions were as follows: Twenty oil paintings and 1 bronze group, by Edwin Willard Deming, illustrating the old-time Indian, his war, hunting, and religious life and mythology; a collection of 27 oil portraits and other paintings by Orlando Rouland, which was opened on the evening of April 2, and was especially noteworthy for the number of prominent men represented; and a collection of 48 paintings, mostly portraits, by the Russian painter, Ossip Perelma, which began on April 28.

Mention should also be made of the ceremonies attending the presentation to the Gallery by the Emmet Statue Committee of the bronze full-length figure of Robert Emmet by Jerome Connor, which took place in the rotunda of the new building on the afternoon of June 28. A distinguished audience, including the President of the United States and other high officials of the Government, was in attendance and several addresses were made.

MEETINGS AND CONGRESSES.

The accommodations afforded by the auditorium and committee rooms in the natural history building were utilized on many occasions. Three courses of lectures, extending from November to April, were given under the auspices of the Washington Society of the Fine Arts, while three other local societies, the Anthropological Society of Washington, the District of Columbia Dental Society, and the Society of Federal Photographers, also made this building their regular meeting place.

The National Academy of Sciences had its annual meeting in April, and lectures were delivered under the auspices of the Washington Academy of Sciences, the War College, the Audubon Society of the District of Columbia, the Bureau of Commercial Economics, the Washington Center of the Drama League of America, the Shakespeare Society of Washington, and George Washington University.

Several bureaus of the Department of Agriculture made use of the auditorium or committee rooms for conferences and hearings, and meetings were held by four societies representing special fields of agricultural subjects. The exhibition halls in the natural history building were opened one evening for the benefit of the Ohio Corn Boys and Domestic Science Girls, then visiting Washington. Other meetings of a governmental character were as follows: By the Na-

tional Association of Postmasters, holding its nineteenth annual convention; by the Bureau of Foreign and Domestic Commerce of the Department of Commerce; by the National Parks Conference, under the auspices of the National Park Service of the Department of the Interior, accompanied by an exhibition of paintings; by the National Research Council; and by the Bureau of Commercial Economics, which gave an exhibition of lantern slides and motion pictures relative to the prevention of contagious diseases, for the benefit of the Council of National Defense. Mr. Eugene E. Thompson addressed the employees of the Institution and its branches on the subject of the first Liberty loan, and two rehearsals of the inter-Departmental chorus in preparation for Flag Day exercises were held in the auditorium.

Receptions were given, on the invitation of the Regents and Secretary of the Institution, on the occasion of a special view of paintings by Mr. Orlando Rouland, and to the Daughters of the American Revolution at the time of their annual congress and the delegates to the eighth annual convention of the American Federation of Arts. The exhibition halls in the natural history building were opened on the evening of June 6 in honor of the visiting Confederate Veterans, Sons of Confederate Veterans, and Daughters of the Confederacy, the receiving party consisting of Secretary and Mrs. Walcott, Miss Mary Lee, and members of the local reception committee.

MISCELLANEOUS.

Over 6,000 duplicate specimens, included in 16 regular sets of mollusks, 19 regular sets of fossils, and a number of special sets, were distributed to schools and colleges. Exchanges for securing additions to the collections involved the use of about 19,500 duplicates, while above 14,000 specimens, chiefly biological and geological, were lent to specialists for study.

The attendance of visitors at the natural history building aggregated 343,183 persons for week days and 63,842 persons for Sundays, being a daily average of 1,096 for the former and 1,227 for the latter. At the arts and industries building and the Smithsonian building, which are open only on week days, the totals were, respectively, 161,700 and 86,336, and the daily averages, 516 and 275.

By the terms of three wills admitted to probate during the year the Museum will be materially benefited, and in another case the testator's desires have already been carried out. Attention has been called to two of these bequests in other connections. That of Henry Ward Ranger is destined to have an important bearing on the future welfare of the National Gallery of Art, while the collection of reptiles left by Julius Hurter, sr., is especially noteworthy and valuable. To the late Miss Sarah J. Farmer, of Eliot, Maine, the Museum is

indebted for the bequest of the models and apparatus left by her father, Moses G. Farmer, a prominent pioneer in the development of the electrical industries, many of whose inventions have for some time been represented in the Museum. Through the wishes of the late Rev. Bruce Hughes, of Lebanon, Pennsylvania, the Smithsonian Institution becomes the recipient of a small sum, the residue of his estate, to found the Hughes Alcove, which will be established in some form in the Museum and be added to perpetually from the interest on principal.

The publications of the year consist of one volume of Proceedings, two volumes of Contributions from the United States National Herbarium, and four Bulletins, besides 76 separate papers, all of which were from the Proceedings, except two from the Contributions and two catalogues of special loan exhibitions in the National Gallery of Art. The total number of copies of publications distributed was about 64,000.

The library obtained, by purchase, gift, and exchange, 1,572 volumes, 65 parts of volumes and 3,656 pamphlets. The more important donations were from Capt. John Donnell Smith, the estate of the late Dr. E. A. Mearns, United States Army, and Dr. William H. Dall.

Respectfully submitted,

Richard Rathbun,
Assistant Secretary in Charge,
United States National Museum.

Dr. Charles D. Walcott,
Secretary of the Smithsonian Institution.
November 10, 1917.

APPENDIX 2.

REPORT OF THE BUREAU OF AMERICAN ETHNOLOGY.

SIR: Pursuant to your request dated July 3, I have the honor to submit the following report of the operations of the Bureau of American Ethnology during the fiscal year ending June 30, 1917, conducted in accordance with the act of Congress approved July 1, 1916, making provisions for the sundry civil expenses of the Government, and with a plan of operations submitted by the ethnologist-in-charge and approved by the Secretary of the Smithsonian Institution. The act referred to contains the following item:

American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archeologic remains, under the direction of the Smithsonian Institution, including necessary employees and the purchase of necessary books and periodicals, $42,000.

In addition to conducting the administrative affairs of the bureau, Mr. F. W. Hodge, ethnologist-in-charge, assisted by Miss Florence M. Poast, continued the preparation of the annotated bibliography of the Pueblo Indians as opportunity offered, adding about 1,000 cards to the 3,800 previously prepared.

SYSTEMATIC RESEARCHES.

In April Mr. Hodge proceeded to New Mexico for the purpose of making final arrangements with the Zuñi Indians for the excavation of the ruins of the large pueblo of Hawikuh, situated on their reservation in the western-central part of the State. This having been accomplished, Mr. Hodge returned to Washington and in the latter part of May again proceeded to Zuñi and established camp at Hawikuh, where excavations were immediately commenced under the joint auspices of the Bureau of American Ethnology and the Museum of the American Indian, Heye Foundation, of New York City, the latter institution bearing most of the expense of the expedition, and assigning Mr. Alanson Skinner and Mr. E. F. Coffin to aid in the work. Authority for conducting the excavations was courteously granted by the Secretary of the Interior.

The excavation of Hawikuh has as its chief object the study of a Zuñi pueblo known to have been inhabited from prehistoric times well into the historic period, for the purpose of determining, so far

as possible, the character and arts of the Zuñi people in early times, as well as the effect of Spanish contact during the sixteenth and seventeenth centuries. Hawikuh was one of the famed "Seven Cities of Cibola" of early Spanish narrative, and its history from the time of its discovery in 1539 until its abandonment in 1670 is quite well known. Consequently the information that the ruins may be expected to yield will in all probability shed considerable light on a phase of the culture of a branch of the Pueblo Indians at an important period in their life.

It is not necessary in this brief report to present the results of the Hawikuh excavations, which were successful beyond anticipation in both a subjective and a objective way. It is expected that a summary report on the work, which was still in progress at the close of the fiscal year, will be presented for publication in the near future.

The beginning of the fiscal year found Dr. J. Walter Fewkes, ethnologist, engaged in an archeological reconnoissance in the vicinity of Gallup, New Mexico. Early in July he proceeded to Mancos, Colorado, examining ancient ruins en route and commencing intensive archeological work in the Mesa Verde National Park, where he remained until the close of September. These excavations, conducted with the cooperation of the Department of the Interior, were in continuation of the work initiated several years ago, of uncovering and repairing the remains of the more important prehistoric ruins in that great area, thus making them available for study and adding to the park's many attractions.

The scene of Doctor Fewkes's activities during this season was one of a cluster of 16 ruins known as the Mummy Lake group, situated above Soda Canyon. None of the walls of this large ruin projected above the surface of the mound of fallen building stones and other débris covered with sagebrush, but on excavation the remains were shown to be those of a rectangular pueblo, 100 by 113 feet, with three stories at the north and an annexed court inclosed by a low wall on the south. By reason of its commanding situation, Doctor Fewkes has named this former pueblo Far View House. After clearing the ruin of the great quantity of débris accumulated during centuries, the tops of the walls of the four kivas uncovered were protected with a capping of concrete, and so far as means would permit the walls of other chambers were similarly treated. As a report on Doctor Fewkes's work at Far View House will appear shortly,[1] it is not necessary to present the details here; but it may be mentioned that the most important result of the study of this site is the fact that a new type of Mesa Verde structure has been revealed, the form and character of which shed light on the close relation of pueblos and cliff dwellings. Indeed,

[1] "A Mesa Verde Pueblo and its People," Smithsonian Report for 1916, pp. 461–488, pl. 1–16, figs. 1–7, Washington, 1917.

Doctor Fewkes reports that Far View House is the only known example of a pure type of pueblo ever completely excavated, the term "pure type" signifying a terraced community building constructed of shaped stones and having circular kivas united with surrounding rectangular rooms. Other significant features are the vaulted roofs of the kivas, the supporting beams of which rest on pilasters, and the presence of a ventilator and a deflector in each kiva, as in the case of certain cliff dwellings. As this pure type of pueblo is entirely prehistoric, it may be regarded as representing a stage in architectural development between the older stage of pueblo structures and the mixed type or more modern form in which the arrangement of the rooms and the art of the mason exhibits a retrogression.

On finishing his work at Far View House, Doctor Fewkes visited Utah primarily for the purpose of determining the geographic distribution of ruins in the northern limits of Pueblo culture. This reconnoissance extended to the Uintah Reservation, where hitherto unknown ruins of Hill Canyon, near Ouray, were examined and where a number of stone towers similar to those along San Juan River were found. These ruins, to which Doctor Fewkes's attention was called by Mr. Kneale, agent for the Uncompahgre Ute, are especially striking owing to their unusual situation on eroded rocks of mushroom shape. These towers mark the northernmost limit of Pueblo culture in eastern Utah, and some of them are especially instructive by reason of their relation to prehistoric towers much further south. An illustrated report on these remains, by Doctor Fewkes, has already appeared.[1]

Mr. James Mooney, ethnologist, was engaged in field work among the Eastern Cherokee of western North Carolina at the opening of the fiscal year, and on his return to Washington, August 10, resumed the translation and annotation of the Sacred Formulas of the Cherokee, as well as the identification of the plants, etc., used by the tribe in its medicine and other rites. Mr. Mooney reports this work to be well advanced, but its complicated nature, coupled with the author's ill health during the year, has made progress somewhat slow. Mr. Mooney also spent considerable time in supplying information on technical subjects for official correspondence.

Dr. John R. Swanton, ethnologist, was occupied chiefly with two lines of investigation—the one historical, the other philological. In July and August he made a thorough examination of the Woodbury Lowery and Brooks collections of manuscripts in the Library of Congress bearing on the early Spanish history of Florida, finding many important items for incorporation in his "History of the Southeast-

[1] "Archeological Investigations in New Mexico, Colorado, and Utah." Smithsonian Misc. Coll., vol. 68, no. 1, pp. 1–38, May, 1917.

ern Tribes." In September Doctor Swanton visited the Newberry Library in Chicago, where other valuable early documents were found in the Edward E. Ayer collection, which subsequently were copied for the bureau's use by the courtesy of the librarian. These latter manuscripts include a report on the Indians of Louisiana by Bienville, a Louisiana memoir with an extended description of the Choctaw, and a memoir by the French captain Berenger, containing, besides historical and ethnological information, vocabularies of the extinct Karankawa and Akokiska tribes. A Spanish census of the Indians of Florida after the period of the English invasions should also be mentioned. For some months after his return Doctor Swanton was engaged in adding to his monograph the historical notes thus obtained, and in copying and translating the more important parts of the manuscripts mentioned, including all of the Berenger memoir.

Although Doctor Swanton's History of the Southeastern Tribes had been completed a year ago, so far as the information was then available, the manuscript discoveries described have enabled him to augment and to improve it substantially, and more recently he has obtained some supplementary notes from the Louisiana Historical Society. The preparation of the maps to accompany the monograph, chiefly from early sources, did not progress as satisfactorily as was hoped, owing largely to pressure of other illustration work, but they are now practically finished.

Doctor Swanton's second paper, also referred to in last year's report remains as then practically complete so far as the available material is concerned, but it awaits further data respecting the social organization of the Chikisaw and the Choctaw. A third paper, on the religious beliefs and medical practices of the Creeks and their congeners, has been brought to the same stage as the last, namely, with all the available material incorporated and arranged, and the footnotes added.

With a view of furnishing the basis of a general study of the social organization of the tribes north of Mexico, Doctor Swanton spent a few weeks collecting material bearing on Indian economic life, but this has been laid aside temporarily on account of the greater urgency of a closer comparative study of the Indian languages of the southeastern part of the United States, particularly as indications of relationship between some of them have already been noted. As a basis for this work Doctor Swanton has recorded a comparative vocabulary of Creek, Choctaw, Alabama, Hitchiti, Natchez, Tunica, Chitimacha, Atakapa, Tonkawa, Comecrudo, Cotoname, Coahuilteco, and Karankawa. Of these languages about 500 words were chosen, but as the lexical material from several of the tribles is scanty, the comparison can never be complete. It was the intention to follow the compilation of this table with a closer comparison of Chitimacha and Ata-

kapa, which show many resemblances, but in the course of the work so many more similarities between Chitimacha and Tunica presented themselves that these were selected instead. In partial furtherance of this research Doctor Swanton proceeded to Louisiana in May, where he remained almost until the close of the fiscal year, visiting, studying, and photographing the mixed Indian population along the Gulf coast in La Fourche and Terra Bonne Parishes, the Chitimacha at Charenton, and the Koasati northeast of Kinder. From the Koasati about 150 pages of native text with interlinear translation were recorded, and 134 pages previously procured from an Alabama Indian in Texas were corrected.

Mr. J. N. B. Hewitt, ethnologist, at the beginning of March went to Canada for the purpose of continuing his Iroquois studies. Establishing headquarters at Brantford, Ontario, he at once undertook the work of revising the extended texts relating to the Iroquois League, recorded during former field trips. Shortly thereafter this work was interrupted when Mr. Hewitt was selected as an official delegate from the council of the Six Nations to attend a condolence and installation ceremony at Munceytown, in which he took a leading part, requiring the intoning of an address of comforting in the Onondaga language and also in acting the part of the Seneca chiefs in such a council. This official recognition gave Mr. Hewitt the rare opportunity of observing how such a ceremony is conducted from an esoteric point of view.

On returning to Brantford, March 16, Mr. Hewitt resumed work on the texts pertaining to the league, which necessitated the reading of the words and the immediate context several times to determine their final form. Moreover, it was desirable to read the texts over with every informant separately in order to obtain a full expression of the informant's knowledge or criticism of the work of another. In this manner it was possible to study about 70 per cent of the texts, and this led, naturally, to the collection of other corrective or amplifying texts and notes. These aggregate 502 pages, comprising 42 topics, recorded from rituals received by Shaman Joshua Buck and Chief Abram Charles. In addition, Mr. Hewitt recorded in English translation three traditions, comprising 45 pages, purporting to relate events and to express ideas alleged to have led to the founding of the League of the Iroquois, showing naïvely the birth of the idea of human brotherhood and fellowhood in contradistinction to mere local tribalism.

Mr. Hewitt also made important discoveries regarding Iroquois social organization, namely, that certain so-called clans do not exist outside of the names used to designate them. For instance, the "Ball" clan is in reality the Hawk clan; the "Hand" clan of the

Cayuga is the Gray Wolf clan, and the "Potato" clan of that tribe is in fact a Duck clan or possibly a Wolf clan. This confusion has been due to popular acceptance of a sobriquet for the real name, hence the doubt in the last instance between the Duck and the Wolf, which it is probable will ultimately be removed. Mr. Hewitt was fortunate also in obtaining a set of wooden masks of the various wind gods, and also two masks of food gods—eight in all. He also procured the gourd rattle used by the late Chief John Buck, a medicine flute, and what was probably the last cradle board with a beaded belt on the reservation.

On returning from the field early in July, Mr. Hewitt undertook at once the editing and copying of the texts of some of his material relating to the Iroquois League. Among these are the following, chiefly in the Onondaga language: (1) The eulogy of the grandsires and founders, one of the essential chants in the condolence ritual, in the version used by the "father side" of the league; (2) the laws governing federal chiefs in intertribal relations; (3) the laws relating to murder committed by a federal chief; (4) the charge made to a newly installed federal chief; (5) the important tradition of the Bear-foot episode; (6) the address made at the lodge of a deceased federal chief three days after his burial; and (7) the laws relating to the nomination and election of a candidate for a federal chiefship. Mr. Hewitt also commenced the translation of the extended "father-side" tradition of the founding of the League by the Deganawida and his associates, read the available proofs of "Seneca fiction, legends, and myths" for the thirty-second annual report, and supplied numerous technical data for use in responses to inquiries by correspondents.

Mr. Francis La Flesche, ethnologist, when not engaged in field-work, was occupied in assembling his notes on the Osage Indians, the greater portion of which consists of phonographic records taken from men versed in the tribal rituals, which evidently were composed for the preservation and transmission of the religious concepts of the tribe. Three forms are used in their construction, namely, recitation, song, and dramatic action. The spoken parts, called "wigie," are intoned by the masters of ceremony and by male members of the various gentes of the tribe who have memorized them. These wigie tell of the genesis of the tribe: they recount the stories of the adoption of life symbols and explain their significance, and narrate the finding and selection of the materials used in making the ceremonial paraphernalia. The songs used by the master of ceremonies, with the aid of a few chosen assistants, make the emotional appeal to the various symbols employed in the ritual. Ceremonial acts, processions, and dances accompany some of the songs and wigie.

The theme of these composite rites is the desire of the people for a long, peaceful life and a never-ending line of descendants, and the wígie, songs, and dramatic acts constitute a supplication to the unseen power for aid toward the realization of this desire. The never-ending life so devoutly sought for the tribe seemed to the people to be exemplified in the unfailing recurrence of night and day, in the constancy of the movements of the heavenly bodies, in the manifestation of a like desire among the living forms upon the earth, and thus to point to an ever-present unseen animating power to which the people must appeal for the granting of their prayers. In this appeal for never-ending life the Osage naturally personified, and to a degree deified, those objects to which, as he thought, the unseen power had granted this form of life. Among these he included the vast space within which the heavenly bodies mysteriously moved and into which all living forms are born and exercise their functions. Thus all aspects of nature are made to play a part in the great drama of life as presented in these rituals.

Early in the year Mr. La Flesche finished transcribing the wígie, as well as his notes on two complete versions and a portion of a third version of the child-naming rituals, comprising 107 typewritten pages. On completing this task he undertook the translation of the Osage personal names in current use and of arranging them by gentes. The Osage generally cling tenaciously to the ancient custom of ceremonially naming their children in the belief that the ceremonies aid the young in attaining old age. In this work Mr. La Flesche was able to determine that many members of the Osage Tribe enrolled as full bloods are in reality of mixed blood. The tabulation of these names by sex and gentes, with their translations, together with a transcription of some characteristic tales, occupies 201 typewritten pages.

During the last four months of the fiscal year Mr. La Flesche was engaged in assembling his notes on the fasting ritual of the Tsízhu Washtage gens. Most of the songs are quite different from those belonging to the fasting rituals of the Hónga, while some of the wígie are the same, these being used in common with slight modifications among the different gentes. These fasting rituals cover 139 completed pages, including the music.

A wígie was obtained by Mr. La Flesche from an old woman during his visit to the Osage in January, 1917. This wígie, which consists of eight pages, fills a hiatus in the rush-mat ceremony previously recorded.

At the opening of the fiscal year Dr. Truman Michelson, ethnologist, was engaged in continuing his studies among the Sauk and Fox Indians of Iowa, the main work accomplished being the phonetic

restoration of a long text, written in the current syllabary, on the origin of the white buffalo dance, intended for publication as a bulletin of the bureau. Considerable information pertaining to a number of sacred bundles of the Fox Indians was obtained, as well as various data of a sociological nature. Nearly 300 personal names were recorded, together with the names of the gentes to which their owners belonged; in this manner about nine-tenths of the population of the Fox Indians has been catalogued.

About the middle of August Doctor Michelson proceeded to Oklahoma where, with the cooperation of the Illinois Centennial Commission, he conducted researches among the Peoria. The ethnology of this tribe, properly speaking, has practically vanished, but their language and folklore still persist, though knowledge thereof is confined to only a few individuals. Contrary to ordinary belief, the Peoria language, phonetically, is extremely complicated. From notes left by the late Dr. A. S. Gatschet, it had been inferred that the Peoria belongs fundamentally with the Chippewa or Ojibwa group of central Algonquian languages, and this was fully confirmed. It is quite clear, however, that there has been another and more recent association with the Sauk, Fox, and Kickapoo group, and Peoria folklore and mythology also point to this double association. The system of consanguinity is clearly that of the Sauk, Fox, and Kickapoo group, rather than that of the Ojibwa. Doctor Michelson recorded, mostly in English, an almost exhaustive collection of Peoria folktales and myths.

After devoting about a month's time to the Peoria Doctor Michelson returned to Iowa and renewed his work among the Sauk and Fox by making a phonetic restoration of a number of texts on minor sacred packs pertaining to the white buffalo dance, as well as by recording about 200 pages of the extremely long myth of the Fox culture hero. Most of the ceremonies in connection with the presentation of a new drum of the so-called religious dance of the Potawatomi of Wisconsin were witnessed, as also were parts of a number of clan feasts.

On returning to Washington in November Doctor Michelson commenced the revision of the English translation of the texts relating to the white buffalo dance, and devoted attention also to paragraphing and punctuating the Indian originals for the purpose of making them correspond with the English equivalents. By the close of the year the English translations were typewritten and put in almost final shape, while little work remained to complete the editing of the native texts.

Mr. J. P. Harrington, ethnologist, spent the entire year in continuation of his intensive study of the Chumashan Tribes of California, obtaining a large body of important information which at present is in various stages of elaboration and which will comprise about 1,200

typewritten pages. From the beginning of the fiscal year until September 15 Mr. Harrington devoted his attention to the Purismeño dialect, the existing vocabularies being corrected by the informant, and many new words and grammatical forms added. The next three weeks were spent on the Obispeño with satisfactory results, inasmuch as the material obtained in former years was more than doubled. The sole informant's feeble health made the recording of this material unusually difficult, but it will prove to be of great local as well as of general interest. The remainder of the fiscal year was devoted to Ventureño and Ineseño. While not so nearly lost as Obispeño, it is too late to obtain complete information on these dialects, but in the process of their study many important points have been determined. It is largely from their study that the picture of former Chumashan life must be reconstructed.

The study of the material culture of the Chumashan Tribes has not been neglected, and in this work archeological material has been of assistance. Among the important points determined are details concerning the making of the ancient deerskin dress of the women, which consisted of a large back flap and a smaller apron.

From the beginning of the fiscal year to the middle of January, 1917, Dr. Leo J. Frachtenberg, special ethnologist, was engaged in field work in the State of Washington, where he devoted special attention to the Quileute Indians and to collecting additional linguistic and mythological material. The ethnologic investigations covered the subjects of history and distribution, manufacture, houses and households, clothing and ornaments, subsistence, travel and transportation, warfare, games and pastimes, social organization and festivals, social customs, religion, medicines, charms and current beliefs, and art, and the recorded results consist of 577 manuscript pages. In addition, Doctor Frachtenberg recorded 156 native songs, including words and translations; he also obtained several hundred native drawings illustrating the material culture of the Quileute, and photographed a like number of ethnologic specimens. Furthermore, he materially added to his linguistic and ethnologic studies of this people, commenced during the preceding year, by collecting several thousand additional grammatical forms and phrases, and by recording 22 new native traditions with interlinear translations, and 3 stories in English. These texts, in the form of field notes, comprise 176 pages. While engaged in this field work Doctor Frachtenberg was instrumental in inducing Mrs. Martha Washburn, of Neah Bay, Mr. and Mrs. Theo R. Rixon, of Clallam Bay, and Mrs. Fannie Taylor, of Moran, to give to the National Museum a part of their collections of Makah and Quileute specimens, including two old totem poles, approximately 100 baskets, and more than 30 other ethnologic specimens. In addition to the Quileute studies mentioned, Doctor Frach-

tenberg collected 88 pages of Makah (Nootka) linguistic data, 57 pages of Quinault (Salish), and 18 pages of Clallam (Lkungen). While in Portland, Oregon, he obtained through the courtesy of the municipal authorities a fine collection of photographs representing several hundred archeological objects owned by the city.

Doctor Frachtenberg returned to Washington early in February. Subsequently, after conference with Dr. Franz Boas, honorary philologist of the bureau, it was arranged that Doctor Frachtenberg prepare for the Handbook of American Indian Languages comparative sketches of the Kalapuya, Molala, Klamath, and Quileute, and possibly one of the Salish languages. He also engaged in the final preparation of his paper, Alsea Texts and Myths, which is now in process of printing as Bulletin 67. He next proceeded to prepare for publication the results of his earlier investigations of the language, ethnology, and mythology of the Kalapuya Indians, which will consist of two papers: A Grammatical Sketch of the Kalapuya Languages and Kalapuya Myths and Texts. The Kalapuya grammatical material consists of extended field notes gathered in 1913 and 1914, and of grammatical notes on the Atfalati collected by Doctor Gatschet in 1877. Doctor Gatschet's material, comprising 421 pages of field notes, is of inestimable value; indeed it is to the efforts of this untiring scholar that we owe the preservation of this most important dialect of the Kalapuya language, since he obtained his material, which includes also some valuable ethnologic data, from the last full-blood Atfalati. Doctor Frachtenberg's own material comprises several thousand grammatical forms, phrases, and vocables, and 32 native texts with interlinear translation—680 pages in all. The preparation of these linguistic data, as well as the work on the Kalapuya myths and texts, is well under way. Six of the texts, comprising 36 pages, have been prepared for publication; five of these are provided with interlinear translation and with voluminous notes in which attention is directed to the occurrence of similar myths among other tribes. During his studies of the Kalapuya languages Doctor Frachtenberg discovered that there is sufficient reason to believe that the Kalapuya, Takelman, and Chinookan languages are genetically related, the determination being based not only on lexical but also on structural and morphological material. This discovery tends to establish a connecting link between some of the languages of California and most of the languages spoken in Oregon.

During the last two weeks of the fiscal year Doctor Frachtenberg was temporarily detailed for special work in the Bureau of Investigation of the Department of Justice.

SPECIAL RESEARCHES.

Dr. Franz Boas, honorary philologist, completed the preparation of his manuscript on the ethnology of the Kwakiutl Indians, about

2,700 pages of which was submitted to the bureau and assigned as the accompanying paper of the thirty-fifth annual report, the composition of which was commenced before the close of the fiscal year. At the same time progress was made on the preparatory work for the second part of the memoir. Under Doctor Boas's direction Miss Mildred Downs listed the incidents of the Kwakiutl mythology preparatory to a discussion of the subject, and necessary additional information for this purpose was obtained from Mr. George Hunt, of Fort Rupert, Vancouver Island. Mr. Hunt submitted in all 400 pages of manuscript in response to questions, and sent botanical specimens that have been identified through the kindness of Dr. N. L. Britton, director of the New York Botanical Garden.

The manuscript for Bulletin 59, Kutenai Tales, has been completed. All the texts having been set up during the preceding year, the abstracts and comparative notes, referring to the pages of the bulletin, were written out (32 pages of printed matter), and a vocabulary (140 pages of manuscript) based on the text was prepared.

For the second part of the Handbook of American Indian Languages Doctor Frachtenberg submitted his sketch of the Alsea grammar, which will be prepared for publication as soon as a sufficient number of texts are available. Considerable progress has been made in the preparation of the Kutenai grammar. Owing to the impossibility of communicating with Mr. Bogoras in Russia, no progress has been made in proof reading the Chukchee grammar, which has been in type for more than three years, but which can not be completed without submitting the proof to the author. During the year, however, Doctor Boas revised the Eskimo texts by Mr. Bogoras, for which a brief ethnological introduction has been written by Dr. Ernest Hawkes.

The results of the extended field work of Mr. James Teit, made possible through the generosity of Mr. Homer E. Sargent of Chicago, are nearing completion. At the present time two manuscripts are well advanced. One of these, consisting of about 1,000 pages, prepared jointly by Doctor Boas and Dr. H. K. Haeberlin, was submitted in May, accompanied with a number of maps showing the distribution of Salishan dialects at various periods. It consists of a discussion of the characteristics of the various dialetic groups, comparative vocabularies on which the deductions are based, and a few simple texts. The material on which these studies are founded was collected from field expeditions by Doctor Boas between 1886 and 1900, and by additional material gathered by Mr. Teit between the latter date and the present year.

Doctor Haeberlin has also undertaken to discuss the Salishan basketry, for which purpose he has made detailed studies of various collections in the United States and Canada. In connection with

this and other necessary researches on the Salishan tribes, Doctor Haeberlin visited British Columbia and Washington in 1915, and again in June, 1917, for the purpose of obtaining additional material. These expeditions were also made possible by the generosity of Mr. Sargent.

In his investigations Doctor Boas has had the valued help of Miss H. A. Andrews and Miss Mildred Downs.

In behalf of the bureau, Mr. W. H. Holmes, of the National Museum, visited New York, Boston, and Cambridge, for the purpose of studying archeological material in the museums of those cities in connection with the completion of Bulletin 60, Handbook of American Antiquities, part 1 of which is in type. The proof reading of this publication was well in hand at the close of the fiscal year, and progress was made by Mr. Holmes in the preparation of part 2.

The study of Indian music, undertaken by Miss Frances Densmore several years ago under the auspices of the bureau, was successfully continued through the year. The proof reading of Bulletin 61, Teton Sioux Music, was brought to completion. A second season of field work was devoted to the Ute Indians, sufficient data being obtained to complete a work on the music of that tribe. Of this material 73 new songs were transcribed and analyzed, 23 songs previously recorded were likewise analyzed, and 5 songs also previously submitted with analyses were further studied. Five group analyses, together with about 30 pages of manuscript description, were prepared. All except about 15 Ute records are now ready for publication; these cover a considerable variety of songs, analyses of which show important differences from songs of other tribes, one peculiarity being an added importance of rhythm.

For purposes of comparison, Miss Densmore undertook on her own account a study of primitive Slovak music, 10 songs of which were analyzed by the method employed in connection with Indian songs, and these were found to contain interesting points of difference.

Through the courtesy of Dr. Dayton C. Miller, of the Case School of Applied Science in Cleveland, Miss Densmore procured graphic evidence of peculiarities of drum and voice combination noted by ear in Indian music. Doctor Miller made two photographs, about 30 feet in length, each representing about 15 seconds' duration of sound. It is the intention to utilize part of these as illustrations in the forthcoming bulletin on Ute music, the songs photographed being Ute dance songs with strong rhythmic peculiarities.

Early in June Miss Densmore proceeded to the White Earth Reservation, Minnesota, for the purpose of conducting a study of the material culture of the Chippewa Indians, and at the close of the year good progress was reported.

Mr. D. I. Bushnell, jr., continued the preparation of the manuscript for the Handbook of Aboriginal Remains East of the Mississippi, about 50,000 words being added to the material previously furnished, not including a portion that was rewritten as a result of a discovery of new and valuable information pertaining to certain localities. Introductions to the archeology of various States remain to be written, but it is believed that both the manuscript and the illustrations for the entire bulletin will be completed before the close of the fiscal year 1918.

Under the joint auspices of the bureau and the National Museum Dr. A. Hrdlička visited in October, 1916, a site at Vero, Florida, at which were found certain human remains reputed to be of great antiquity. As a summary account of Doctor Hrdlička's observations has already appeared in Smithsonian Miscellaneous Collections (vol. 66, no. 17, pp. 24–29, 1917) and an extended report will be published in Bulletin 66 of the bureau, now in press, it need only be mentioned that a thorough inquiry has resulted decisively against the assumption of great antiquity of the remains. The pottery and the bone and stone objects found in association with the human burials are identical with similar artifacts of the Florida and other southeastern Indians, while the bones themselves without exception exhibit modern features, with numerous characteristics that permit their identification as purely Indian.

Owing to the fact that Dr. A. L. Kroeber, of the University of California, found it expedient to elaborate certain portions of his handbook of the Indians of California, it was not practicable to submit the entire manuscript before the close of the fiscal year, but at this writing there is every prospect that the work will be ready for publication within a short time.

MANUSCRIPTS.

The following manuscripts, exclusive of those submitted for publication, were received by the bureau:

Photostat copy of a San Blas vocabulary, recorded by Ensign J. M. Creighton, United States Navy, transmitted to the Smithsonian Institution by the Secretary of the Navy.

Philippine songs presented by Mr. E. H. Hammond, of Albuquerque, New Mexico.

Photograph of a picture writing on elk skin by Washakie, the Shoshoni chief, with a key thereto.

Reports on prehistoric ruins in Arizona, with numerous photographs, prepared by the late S. J. Holsinger, of the General Land Office, and deposited in the bureau by the United States Forest Service.

Abnaki hymns from John Tahamont, of Pierreville, Quebec, presented by George G. Heye, Esq.

PUBLICATIONS.

The editing of the publications of the bureau was continued through the year by Mr. J. G. Gurley, assisted as occasion required by Mrs. Frances S. Nichols. The status of the publications is presented in the following summary:

PUBLICATIONS ISSUED.

Thirty-first Annual Report. Accompanying paper: Tsimshian Mythology (Boas).

Coos, An Illustrative Sketch, separate (Frachtenberg). Bulletin 40, part 2 (Boas).

Bulletin 55, Ethnobotany of the Tewa Indians (Robbins, Harrington, Freire-Marreco).

List of Publications of the Bureau.

PUBLICATIONS IN PRESS OR IN PREPARATION.

Thirty-second Annual Report. Accompanying paper: Seneca Fiction, Legends, and Myths (Hewitt and Curtin).

Thirty-third Annual Report. Accompanying papers: (1) Uses of Plants by the Indians of the Nebraska Region (Gilmore); (2) Preliminary Account of the Antiquities of the Region between the Mancos and La Plata Rivers in Southwestern Colorado (Morris); (3) Designs on Prehistoric Hopi Pottery (Fewkes); (4) The Hawaiian Romance of Laieikawai (Beckwith).

Thirty-fourth Annual Report. Accompanying paper: An Introductory Study of the Arts, Crafts, and Customs of the Guiana Indians (Roth).

Thirty-fifth Annual Report. Accompanying paper: Ethnology of the Kwakiutl Indians (Hunt, edited by Boas).

Bulletin 59, Kutenai Tales (Boas).

Bulletin 60, Handbook of Aboriginal American Antiquities. Part 1. Introductory: The Lithic Industries (Holmes).

Bulletin 61, Teton Sioux Music (Densmore).

Bulletin 63, Analytical and Critical Bibliography of the Tribes of Tierra del Fuego and Adjacent Territory (Cooper).

Bulletin 64, The Maya Indians of Southern Yucatan and Northern British Honduras (Gann).

Bulletin 65, Archeological Explorations in Northeastern Arizona (Kidder and Guernsey).

Bulletin 66, Recent Discoveries of Remains Attributed to Early Man in America (Hrdlička).

Bulletin 67, Alsea Texts and Myths (Frachtenberg).

The distribution of publications has been continued under the immediate charge of Miss Helen Munroe and at times by Mr. E. L. Springer, of the Smithsonian Institution, assisted during the first part of the year by Miss Lena V. Schelski, and latterly by Miss Ora A. Sowersby, stenographer and typewriter. Notwithstanding conditions incident to the war and the consequent necessity of withholding the transmission of various foreign shipments, publications were distributed as follows:

	Copies.
Annual reports and separates	5,654
Bulletins and separates	5,694
Contributions to North American Ethnology and separates	28
Introductions	7
Miscellaneous publications	101
Total	11,484

ILLUSTRATIONS.

Mr. DeLancey Gill, with the assistance of Mr. Albert E. Sweeney, continued the preparation of the illustrations required for the publications of the bureau and devoted the usual attention to photographing visiting Indians. The results of this work may be summarized as follows:

Photographic prints for distribution and office use	576
Negatives of ethnologic and archeologic subjects	173
Negative films developed from field exposures	214
Photostat prints from books and manuscripts	950
Drawings made	54
Mounts used	62
Portrait negatives of visiting Indians (Creek 9, Arapaho 4, Cheyenne 16)	29
Negatives retouched	75
Illustration proofs examined at Government Printing Office	9,000
Illustrations submitted for reproduction and engraver's proofs edited	731

LIBRARY.

The reference library of the bureau continued in the immediate care of Miss Ella Leary, librarian, assisted by Mr. Charles B. Newman. During the year 435 books were accessioned, of which 97 were purchased, 286 acquired by gift or exchange, and 52 by the entry of newly bound volumes of periodicals previously received. In addition the bureau acquired 388 pamphlets. The aggregate number of books in the library at the close of the year was 21,750; of pamphlets, about 13,848. In addition there are many volumes of unbound periodicals. Several new periodicals were added to the exchange list and about 50 defective series were either wholly or partly completed. As might be expected, the publication of various European periodicals devoted to anthropology has either been suspended or has ceased entirely. Largely with the assistance of Mrs. Frances S. Nichols many of the older books and pamphlets were newly catalogued by both subject and author, and thus made more readily available. Of 133 volumes sent to the bindery about half were returned before the close of the year. Books borrowed from the Library of Congress numbered about 400.

COLLECTIONS.

The following collections were acquired by the bureau, by members of its staff, or by those detailed in connection with its reseuches, and have been transferred to the National Museum:

Six ethnologic objects from British Guiana, presented by Dr. Walter E. Roth, of Marlborough, Pomeroon River, British Guiana. (60049.)

A small collection of archeological objects of earthenware, jadeite, etc., from the Kiché district of Totonicapan, Guatemala. (61007.)

A collection of archeological objects, including human bones, gathered by Mr. Neil M. Judd in Utah. (60194.)

Seven specimens found by Mr. Joseph Dame in Millard County, Utah, and purchased from him through Mr. Neil M. Judd. (60195.)

A collection of archeological objects and skeletal material gathered by Dr. Walter Hough at the Luna pit village in western New Mexico. (60198.)

Ten baskets of the Guiana Indians of South America, presented to the bureau by Dr. Walter E. Roth, of Marlborough, Pomeroon River, British Guiana. (60452.)

Seventeen prehistoric pottery vessels, one piece of matting, and a few small objects collected by F. W. Hodge in a cist in a cave in a southern wall of Cibollita Valley, Valencia County, New Mexico. (60453.)

Twenty-five archeological specimens gathered by Dr. J. Walter Fewkes from ancient ruins near Gallup, New Mexico. (60502.)

A small black-ware vase from Santa Clara pueblo, New Mexico, presented by Robert H. Chapman, of Washington, District of Columbia. (60623.)

Twelve stone artifacts from Reeves Mill, near Pitman, Gloucester County, New Jersey, presented by Mrs. M. B. C. Shuman. (60836.)

Archeological material collected by Dr. J. Walter Fewkes from excavations conducted at Mummy Lake Ruins, Mesa Verde National Park, Colorado. (60880.)

Archeological material collected by Dr. J. Walter Fewkes from excavations conducted at Oak Tree House, Mesa Verde National Park, Colorado. (60901.)

An Assiniboine headdress from Alberta, Canada, presented by Mr. Robert H. Chapman, Washington, District of Columbia. (61097.)

Skulls, skeletons, and parts of skeletons, an Indian ornament embedded in stone, and pottery fragments, collected in the vicinity of Vero and Fort Myers, Florida, by Dr. A. Hrdlička. (61291.)

Seven baskets made by the Koasati Indians of Louisiana, collected by Dr. John R. Swanton. (61315.)

PROPERTY.

Furniture was purchased to the amount of $196.25; the cost of typewriting machines was $206, and of a camera $10.50, making a total of $412.75 expended for furniture and apparatus. On the whole the furniture of the bureau is in good condition, but there are a few unserviceable pieces that should be replaced, while need of a few filing cases for current notes and manuscripts is felt.

MISCELLANEOUS.

Quarters.—One of the rooms on the third floor of the north tower of the Smithsonian building, occupied by the bureau, was painted, and the electric lighting of three rooms improved.

Personnel.—The only change in the personnel of the bureau was the appointment of Miss Ora A. Sowersby, stenographer and typewriter, on February 14, 1917, to succeed Miss Lena V. Schelski, transferred. A temporary laborer was employed from time to time when required.

Clerical.—The correspondence and other clerical work of the office, including the copying of manuscripts, has been conducted with the aid of Miss Florence M. Poast, clerk to the ethnologist-in-charge; Miss May S. Clark, and Mrs. Frances S. Nichols. Miss Sowersby was assigned to the division of publications of the Smithsonian Institution for duty in connection with correspondence arising from the distribution of the bureau's publications.

Respectfully submitted,

F. W. Hodge,
Ethnologist-in-Charge.

Dr. Charles D. Walcott,
Secretary of the Smithsonian Institution.

APPENDIX 3.

REPORT ON THE INTERNATIONAL EXCHANGES.

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1917.

The regular congressional appropriation for the support of the service during the year, including the allotment for printing and binding, was $32,200, but in order to enable the Institution to meet the very high ocean freight rates on foreign shipments Congress granted an additional appropriation of $3,500. The repayments from departmental and other establishments aggregated $3,687.58, making the total available resources for carrying on the system of exchanges $39,387.58.

During the year 1917 the total number of packages handled was 268,625, which weighed 200,193 pounds.

The number and weight of the packages of different classes are indicated in the following table:

	Packages.		Weight (pounds).	
	Sent.	Received.	Sent.	Received.
United States parliamentary documents sent abroad	[illegible]		[illegible]	
Publications received in return for parliamentary documents		[illegible]		[illegible]
United States departmental documents sent abroad	[illegible]		110,510	
Publications received in return for departmental documents		[illegible]		[illegible]
Miscellaneous scientific and literary publications sent abroad	[illegible]		[illegible]	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		[illegible]		[illegible]
Total	[illegible]	[illegible]	[illegible]	[illegible]
Grand total	268,625		[illegible]	

As referred to in previous reports, many returns for publications sent abroad reach their destinations in this country direct by mail and not through the exchange service.

Shipments are still suspended to Austria, Belgium, Bulgaria, Germany, Hungary, Montenegro, Roumania, Russia, Serbia, and Turkey. Shipments both to and from Germany, which were arranged by the

Institution through the State Department, as referred to in the last report, were discontinued at the outbreak of hostilities between the United States and Germany. The further efforts of the Russian Commission of International Exchanges to resume shipments were not successful, and the commission stated that it would be necessary to withhold consignments until the end of the war.

In accordance with the proclamation of the British Government prohibiting the importation into the United Kingdom of books in bulk, it was necessary to suspend shipments to that country for a time. However, the London agents of the Institution, Messrs. William Wesley & Son, succeeded in procuring from the Royal Commission on Paper a special license to import consignments of international exchanges into England. Owing to the lack of requisite ocean transportation facilities, it was also necessary to suspend shipments for a time to Norway, Sweeden, Denmark, and Holland.

The director of the Government Press at Cairo advises the Institution that four boxes of Egyptian exchange en route to this country were lost at sea, and suggests that shipments be withheld until the end of the war. This suggestion will be followed. On account of the abnormal conditions in the Mediterranean, shipments to Greece will also be suspended.

Since the beginning of the war the Institution has suffered the loss of only three shipments from hostile action. One small shipment—consisting of 24 governmental documents—was lost in transit to India during the first year of the war. Through the sinking of a vessel by a warship during the past year 18 packages in transit to India were also lost. Twenty-one boxes for the French Bureau of Exchanges were lost when the steamship *Juno* was torpedoed in February last. Nineteen of these contained miscellaneous governmental and scientific publications for distribution to various addresses throughout France and the other two the regular series of United States official documents for deposit in the National Library at Paris and the office of the prefect of the Seine.

In the early part of the present fiscal year the Italian Exchange office in Rome reported that one of the boxes of the consignment sent to that office in July, 1915, had not been delivered. Steps taken to have the box traced were unsuccessful.

Wherever possible the Institution has, as formerly in the case of lost consignments, procured duplicate copies of the publications contained in the above-mentioned boxes.

The Government publications office at Bulaq—which acts as the Egyptian Exchange agency—has kindly taken charge until the close of the war of a box addressed to the Jewish Agricultural Experiment Station, Haifa, Palestine, which was detained at Alexandria.

I am pleased to state that the four boxes held at Bahia, Brazil, to which reference was made in the 1915 report, have been released and forwarded to the Government printing works at Pretoria.

Reference has previously been made to the custom of the Government of India to refer requests from establishments in this country for Indian official documents to the exchange service for indorsement. The director of the Government Press at Cairo has requested that the Institution take similar action on applications for Egyptian official publications. This request has been granted.

Of the 1,217 boxes used in forwarding exchanges to foreign agencies for distribution during 1917, 170 contained full sets of United States official documents for authorized depositories, and 1,047 were filled with departmental and other publications for depositories of partial sets and for miscellaneous correspondents. The number of boxes sent to each foreign country and the dates of transmission are shown in the following table:

Consignments of exchanges for foreign countries.

Country.	Number of boxes.	Date of transmission.
Argentina	41	July 21, Sept. 13, Nov. 15, 1916; Jan. 13, Mar. 30, June 8, 1917.
Barbados	1	May 28, 1917.
Bolivia	2	Aug. 29, 1916; Mar. 31, 1917.
Brazil	28	July 25, Sept. 14, Nov. 18, 1916; Jan. 15, Mar. 29, June 9, 1917.
British Colonies	8	July 19, Aug. 3, 23, Sept. 11, Oct. 9, Nov. 1, 24, Dec. 20, 1916; Feb. 7, Apr. 14, 1917.
British Guiana	2	Sept. 21, 1916; Feb. 16, 1917.
Canada	16	Sept. 25, Dec. 18, 1916; Feb. 17, May 17, 1917.
Chile	10	July 26, Sept. 18, Nov. 16, 1916; Jan. 18, Mar. 30, June 11, 1917.
China	26	Sept. 5, Oct. 25, Nov. 28, 1916; Feb. 6, Mar. 8, May 23, 1917.
Colombia	22	July 10, Oct. 7, Nov. 12, Dec. 13, 1916; May 10, 1917.
Costa Rica	13	Aug. 12, Oct. 25, 1916; Jan. 17, Mar. 30, Apr. 6, June 13, 1917.
Cuba	4	Sept. 25, Dec. 18, 1916; Feb. 17, May 17, 1917.
Denmark	30	Aug. 9, Sept. 29, 1916; Jan. 6, Mar. 12, May 21, 1917.
Ecuador	4	Aug. 3, 1916; Apr. 10, 1917.
Egypt	8	Aug. 11, 1916; May 16, 1917.
France	122	July 10, Aug. 19, Oct. 12, Nov. 14, 1916; Jan. 10, Mar. 21, May 9, 1917.
Germany	46	Dec. 16, 1916.
Great Britain and Ireland	150	July 20, Aug. 8, 23, Sept. 11, Oct. 9, Nov. 1, 24, Dec. 20, 1916; Feb. 7, Apr. 14, 18, June 4, 1917.
Greece	7	Aug. 11, Nov. 9, 1916.
Guatemala	3	Aug. 30, 1916; Apr. 6, 1917.
Haiti	4	Sept. 25, Dec. 18, 1916; Feb. 17, May 17, 1917.
Honduras	2	Aug. 30, 1916; Apr. 4, 1917.
India	30	July 19, Aug. 3, 23, Sept. 11, Oct. 9, Nov. 1, 24, Dec. 20, 1916; Feb. 7, Apr. 14, 1917.
Italy	60	July 6, Aug. 4, Sept. 22, Nov. 10, Dec. 21, 1916; Jan. 20, Apr. 20, June 4, 1917.
Jamaica	5	Aug. 29, 1916; Feb. 9, May 24, 1917.
Japan	30	July 7, Aug. 10, Nov. 25, 1916; Jan. 19, Mar. 7, May 15, 1917.

Consignments of exchanges for foreign countries—Continued.

Country.	Number of boxes.	Date of transmission.
Korea	1	Aug. 30, 1916.
Liberia	2	Aug. 29, 1916; May 25, 1917.
Lourenço Marques	1	May 29, 1917.
Mexico	4	Sept. 23, Dec. 13, 1916; Feb. 17, May 17, 1917.
Netherlands	30	July 7, Aug. 5, Sept. 25, Nov. 4, 1916; Jan. 5, 1917.
New South Wales	43	July 20, Aug. 24, Sept. 25, Oct. 16, Dec. 6, 1916; Jan. 13, Feb. 15, Apr. 16, June 13, 1917.
New Zealand	17	July 20, Aug. 26, Oct. 20, Dec. 12, 1916; Feb. 13, Apr. 17, June 21, 1917.
Nicaragua	3	Aug. 30, 1916; Apr. 10, 1917.
Norway	13	Aug. 9, Sept. 26, Nov. 11, 1916; Jan. 6, Mar. 14, 1917.
Paraguay	1	Aug. 30, 1916.
Peru	13	July 20, Sept. 18, Nov. 14, 1916; Mar. 29, June 13, 1917.
Portugal	15	Aug. 10, Sept. 25, Nov. 20, 1916; Mar. 15, May 22, 1917.
Queensland	11	July 20, Aug. 26, Oct. 20, Dec. 12, 1916; Feb. 13, Apr. 17, June 21, 1917.
Salvador	4	Aug. 1, 1916; Apr. 7, 1917.
Siam	3	Aug. 30, 1916; Feb. 16, 1917.
South Australia	14	July 20, Aug. 26, Oct. 18, Dec. 14, 1916; Feb. 13, Apr. 17, June 22, 1917.
Spain	22	Aug. 11, Sept. 30, Nov. 17, 1916; Jan. 11, May 14, 1917.
Sweden	43	Aug. 4, Sept. 27, Nov. 11, 1916; Jan. 18, May 1, 1917.
Switzerland	53	Sept. 25, Aug. 9, Nov. 13, 1916; Jan. 10, May 9, 1917.
Tasmania	10	July 19, Aug. 3, 23, Sept. 11, Oct. 9, Nov. 1, 24, Dec. 20, 1916; Jan. 23, Mar. 21, May 9, 1917.
Trinidad	3	Aug. 29, 1916; May 23, 1917.
Union of South Africa	17	July 6, Sept. 30, Nov. 11, 1916; Jan. 10, 1917.
Uruguay	13	July 27, Sept. 16, Nov. 17, 1916; Jan. 17, Mar. 29, June 11, 1917.
Venezuela	10	Aug. 12, Oct. 20, 1916; Jan. 17, Mar. 29, June 12, 1917.
Victoria	22	July 20, Aug. 26, Oct. 17, Dec. 9, 1916.
Western Australia	13	July 19, Aug. 3, 23, Sept. 11, Oct. 9, Nov. 1, 24, Dec. 20, Feb. 7, Apr. 14, 1917.
Windward and Leeward Islands	1	May 26, 1917.

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS.

Ninety-one sets of United States governmental documents were received for distribution to foreign depositories in accordance with treaty stipulations and under the authority of the congressional resolutions of March 2, 1867, and March 2, 1901. A communication was received during the year from the assistant secretary to the Government of India, department of education, stating that the United States governmental documents sent to his department are turned over to the Imperial Library at Calcutta, and requesting that future consignments be addressed directly to that library.

A list of the foreign depositories is given below. Consignments for those countries to which shipments are suspended on account of

the war are being held at the Institution for transmission to the various depositories at the close of hostilities.

DEPOSITORIES OF FULL SETS.

ARGENTINA: Ministerio de Relaciones Exteriores, Buenos Aires.
AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
AUSTRIA: K. K. Statistische Zentral-Kommission, Vienna.
BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the Grand Duchy of Baden.)
BAVARIA: Königliche Hof- und Staats-Bibliothek, Munich.
BELGIUM: Bibliothèque Royale, Brussels.
BRAZIL: Bibliotheca Nacional, Rio de Janeiro.
BUENOS AIRES: Biblioteca de la Universidad Nacional de La Plata. (Depository of the Province of Buenos Aires.)
CANADA: Library of Parliament, Ottawa.
CHILE: Biblioteca del Congreso Nacional, Santiago.
CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA: Secretaria de Estado (Asuntos Generales y Canje Internacional), Habana.
DENMARK: Kongelige Bibliotheket, Copenhagen.
ENGLAND: British Museum, London.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Deutsche Reichstags-Bibliothek, Berlin.
GLASGOW: City Librarian, Mitchell Library, Glasgow.
GREECE: Bibliothèque Nationale, Athens.
HAITI: Secrétaire d'État des Relations Extérieures, Port au Prince.
HUNGARY: Hungarian House of Delegates, Budapest.
INDIA: Imperial Library, Calcutta.
IRELAND: National Library of Ireland, Dublin.
ITALY: Biblioteca Nazionale Vittorio Emanuele, Rome.
JAPAN: Imperial Library of Japan, Tokyo.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
MANITOBA: Provincial Library, Winnipeg.
MEXICO: Instituto Bibliográfico, Biblioteca Nacional, Mexico.
NETHERLANDS: Library of the States General, The Hague.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Storthingets Bibliothek, Christiania.
ONTARIO: Legislative Library, Toronto.
PARIS: Préfecture de la Seine.
PERU: Biblioteca Nacional, Lima.
PORTUGAL: Bibliotheca Nacional, Lisbon.
PRUSSIA: Königliche Bibliothek, Berlin.
QUEBEC: Library of the Legislature of the Province of Quebec, Quebec.
QUEENSLAND: Parliamentary Library, Brisbane.
RUSSIA: Imperial Public Library, Petrograd.
SAXONY: Königliche Oeffentliche Bibliothek, Dresden.
SERBIA: Section Administrative du Ministère des Affaires Étrangères, Belgrade.

SOUTH AUSTRALIA: Parliamentary Library, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultative de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Fédérale, Berne.
TASMANIA: Parliamentary Library, Hobart.
TURKEY: Department of Public Instruction, Constantinople.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevidio.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
WÜRTTEMBERG: Königliche Landesbibliothek, Stuttgart.

DEPOSITORIES OF PARTIAL SETS.

ALBERTA: Provincial Library, Edmonton.
ALSACE-LORRAINE: K. Ministerium für Elsass-Lothringen, Strassburg.
BOLIVIA: Ministerio de Colonización y Agricultura, La Paz.
BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
BRITISH COLUMBIA: Legislative Library, Victoria.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
BULGARIA: Minister of Foreign Affairs, Sofia.
CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.
ECUADOR: Biblioteca Nacional, Quito.
EGYPT: Bibliothèque Khédiviale, Cairo.
FINLAND: Chancery of Governor Helsingfors.
GUATEMALA: Secretary of the Government, Guatemala.
HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.
HESSE: Grossherzogliche Hof-Bibliothek, Darmstadt.
HONDURAS: Secretary of the Government, Tegucigalpa.
JAMAICA: Colonial Secretary, Kingston.
LIBERIA: Department of State, Monrovia.
LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.
LÜBECK: President of the Senate.
MADRAS, PROVINCE OF: Chief Secretary to the Government of Madras, Public Department, Madras.
MALTA: Lieutenant Governor, Valetta.
MONTENEGRO: Ministère des Affaires Étrangères, Cetinje.
NEW BRUNSWICK: Legislative Library, Fredericton.
NEWFOUNDLAND: Colonial Secretary, St. John's.
NICARAGUA: Superintendente de Archivos Nacionales, Managua.
NORTHWEST TERRITORIES: Government Library, Regina.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PANAMA: Secretaria de Relaciones Exteriores, Panama.
PARAGUAY: Oficina General de Inmigracion, Asuncion.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
ROUMANIA: Academia Romana, Bucharest.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.
UNITED PROVINCES OF AGRA AND OUDH: Under Secretary to Government, Allahabad.
VIENNA: Bürgermeister der Haupt- und Residenz-Stadt.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNALS.

Following is a complete list of the Governments to which copies of the daily issue of the Congressional Record are now sent. The records for those countries to which it is not possible to forward consignments at present are being held at the Institution:

Argentine Republic.	France.	Prussia.
Australia.	Great Britain.	Queensland.
Austria.	Greece.	Roumania.
Baden.	Guatemala.	Russia.
Belgium.	Honduras.	Serbia.
Bolivia.	Hungary.	Spain.
Brazil.	Italy.	Switzerland.
Buenos Aires, Province of.	Liberia.	Transvaal.
Canada.	New South Wales.	Union of South Africa.
Costa Rica.	New Zealand.	Uruguay.
Cuba.	Peru.	Venezuela.
Denmark.	Portugal.	Western Australia.

LIST OF BUREAUS OR AGENCIES THROUGH WHICH EXCHANGES ARE TRANSMITTED.

The following is a list of the bureaus or agencies through which exchanges are transmitted:

ALGERIA, via France.

ANGOLA, via Portugal.

ARGENTINA: Comisión Protectora de Bibliotecas Populares, Santa Fé 890, Buenos Aires.

AUSTRIA: K. K. Statistische Zentral-Kommission, Vienna.[1]

AZORES, via Portugal.

BELGIUM: Service Belge des Échanges Internationaux, Rue des Longs-Chariots 46, Brussels.[1]

BOLIVIA: Oficina Nacional de Estadística, La Paz.

BRAZIL: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.

BRITISH COLONIES: Crown Agents for the Colonies, London.

BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.

BRITISH HONDURAS: Colonial Secretary, Belize.

BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.[1]

CANARY ISLANDS, via Spain.

CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.

CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.

COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.

DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.

ECUADOR: Ministerio de Relaciones Exteriores, Quito.

EGYPT: Government Publications Office, Printing Department, Cairo.[1]

[1] Shipments suspended on account of the war.

FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.

GERMANY: Amerika-Institut, Berlin, N. W. 7.[1]

GREAT BRITAIN AND IRELAND: Messrs. William Wesley & Son, 28 Essex Street, Strand, London.

GREECE: Bibliothèque Nationale, Athens.[1]

GREENLAND, via Denmark.

GUADELOUPE, via France.

GUATEMALA: Instituto Nacional de Varones, Guatemala.

GUINEA, via Portugal.

HAITI: Secrétaire d'État des Relations Extérieures, Port au Prince.

HONDURAS: Biblioteca Nacional, Tegucigalpa.

HUNGARY: Dr. Julius Pikler, Municipal Office of Statistics, Váci-utca 80, Budapest.[1]

ICELAND, via Denmark.

INDIA: India Store Department, India Office, London.

ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.

JAMAICA: Institute of Jamaica, Kingston.

JAPAN: Imperial Library of Japan, Tokyo.

JAVA, via Netherlands.

KOREA: Government General, Keijo.

LIBERIA: Bureau of Exchanges, Department of State, Monrovia.

LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.

LUXEMBURG, via Germany.

MADAGASCAR, via France.

MADEIRA, via Portugal.

MONTENEGRO: Ministère des Affaires Étrangères, Cetinje.[1]

MOZAMBIQUE, via Portugal.

NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université, Leyden.

NEW GUINEA, via Netherlands.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: Dominion Museum, Wellington.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

NORWAY: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.

PANAMA: Secretaria de Relaciones Exteriores, Panama.

PARAGUAY: Servicio de Canje Internacional de Publicaciones, Sección Consular y de Comercio, Ministerio de Relaciones Exteriores, Asuncion.

PERSIA: Board of Foreign Missions of the Presbyterian Church, New York City.

PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.

PORTUGAL: Serviço de Permutações Internacionaes, Inspecção Geral das Bibliothecas e Archivos Publicos, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

ROUMANIA: Academia Romana, Bucharest.[1]

RUSSIA: Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, Petrograd.[1]

SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.

SERBIA: Section Administrative du Ministère des Affaires Étrangères, Belgrade.[1]

SIAM: Department of Foreign Affairs, Bangkok.

[1] Shipments suspended on account of the war.

South Australia: Public Library of South Australia, Adelaide.
Spain: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
Sumatra, via Netherlands.
Sweden: Kungliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.
Syria: Board of Foreign Missions of the Presbyterian Church, New York.
Tasmania: Secretary to the Premier, Hobart.
Trinidad: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.
Tunis, via France.
Turkey: American Board of Commissioners for Foreign Missions, Boston.[1]
Union of South Africa: Government Printing Works, Pretoria, Transvaal.
Uruguay: Oficina de Canje Internacional, Montevideo.
Venezuela: Biblioteca Nacional, Caracas.
Victoria: Public Library of Victoria, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Windward and Leeward Islands: Imperial Department of Agriculture, Bridgetown, Barbados.

Respectfully submitted.

C. W. Shoemaker,
Chief Clerk, International Exchange Service.

Dr. Charles D. Walcott,
Secretary of the Smithsonian Institution.

August 15, 1917.

Appendix 4.

REPORT ON THE NATIONAL ZOOLOGICAL PARK.

Sir: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1917:

There was allowed by Congress in the sundry civil bill the sum of $100,000 for all expenses, except printing and binding, for which $200 additional was granted.

The continued increase from year to year in the cost of nearly all supplies used at the park has so greatly enlarged the bills for maintenance expenses that very little could be done this year in the way of permanent improvements on buildings and grounds. The collections have, nevertheless, been kept in excellent condition and at nearly the normal numbers, though much-needed repairs and alterations, for the comfort and safety of the public, or to improve housing conditions of animals, could not be made. The number of specimens is slightly below that for a number of years, but the actual value and scientific importance of the collection is probably as great as at any time in the history of the park.

In October, 1916, Dr. Frank Baker, for 26 years the superintendent, tendered his resignation to take effect November 1. To quote from an editorial in the Washington Times of October 6, entitled "The loss of Dr. Baker":

> The resignation of Dr. Frank Baker as superintendent of the National Zoological Park marks the close of 26 years of valuable service in that capacity.
>
> A reading of the reports of the Smithsonian Institution shows how much the Zoo here has developed under Doctor Baker, until [redacted] now possesses one of the most varied and interesting collections of animals of any such institution in the country.
>
> The average citizen does not bother much about zoos except as a form of Sunday afternoon entertainment for children. But the educational value of the parks is becoming more generally recognized. School children of Washington are now sent to the Zoo [redacted] observe the animals, and they can learn and assimilate much more there in a few visits than they could accumulate in weeks of studying geographies.
>
> As a professor of anatomy for 33 years at Georgetown University, as president of the National Association of Anatomists, and as an active member of half a dozen other scientific bodies, Doctor Baker has also attained note outside his work at the Zoo. His capacity for work is suggested in the calm announce-

ment that he, at the age of 75 years, must retire from the Zoo, not to seek leisure, but because of the pressure of other duties. Doctor Baker is one of a notable group of scientists to be found in Washington whose reputation is world-wide.

ACCESSIONS.

Gifts.—Animals to the number of 99 were presented by friends of the park, or placed on indefinite deposit. These include many of the more common species of the native fauna as well as some especially desirable animals rarely obtained.

One of the most notable gifts was that of five adult Rocky Mountain sheep received from the Canadian Government, through Mr. J. B. Harkin, commissioner of Dominion parks. These animals were captured in the Rocky Mountains Park near Banff, Alberta, and reached Washington March 7 in perfect condition. The shipment included one 5-year-old ram, a younger ram, and three ewes. A ewe lamb was born on May 27. Two paddocks were opened together to give the sheep sufficient range, and the exhibit is one of the most important now shown by the park. The animals are doing well to date and although the wild sheep is one of the species most difficult to keep in eastern zoological gardens it is hoped that the animals comprising this accession may be kept on show for a considerable time. The Duke of Bedford made a further gift of four Bedford deer, or Manchurian stags, from his collection at Woburn Abbey, England. The Bedford deer (*Cervus xanthropygus*) is one of a large group of Old World deer related to the American elk or wapiti, and has not heretofore been exhibited. The animals received have been given a commodious yard bordering the creek on the eastern side of the park, near the yaks, and are doing splendidly in their new home. A thrifty fawn was born June 14. Mr. Victor J. Evans, of Washington, District of Columbia, showed continued interest in the exhibit by depositing some desirable Australian marsupials, including two wombats and a nail-tailed wallaby, both new to the collection.

The complete list of the donors and gifts is as follows:

Adams Express Co., Washington, District of Columbia, mink.

Mr. and Mrs. Carl E. Akeley, New York City, vervet monkey and a bonnet monkey.

Mrs. Ida Bangs, Washington, District of Columbia, yellow-naped parrot.

Mr. J. C. Beard, Brightwood, District of Columbia, two barred owls.

The Duke of Bedford, Woburn Abbey, England, four Bedford deer.

Mr. C. E. Brewster and Dr. F. Kent, Eagle Pass, Texas, Inca dove, a hybrid quail, and eight chestnut-bellied scaled quails.

Mrs. C. S. Briggs, Washington, District of Columbia, alligator.

Mrs. F. S. Brown, Washington, D. C., sparrowhawk.

Postmaster General Burleson, Washington, District of Columbia, alligator.

Mrs. E. Caminetti, Washington, District of Columbia, yellow rail.

Canadian Government, through Hon. J. B. Harkin, 5 Rocky Mountain sheep.

Prof. W. E. Castle, Bussey Institution, Harvard University, 4 Peruvian wild guinea-pigs.

Mrs. Chatham, Washington, District of Columbia, yellow-headed parrot.

Mr. D. Crovo, Washington, District of Columbia, boa constrictor and a murine opossum.

Mr. John O. Darlington, Washington, District of Columbia, 2 alligators.

Dr. Ned Dearborn, Laurel, Maryland, common ferret.

Mr. R. F. Dunham, Allegan, Michigan, alligator.

Dr. W. O. Emery, Washington, District of Columbia, Cooper's hawk.

Mr. Victor J. Evans, Washington, District of Columbia, nail-tailed wallaby and 2 wombats.

Mr. E. G. Fletcher, Washington, District of Columbia, alligator.

Mr. J. M. Frank, jr., Washington, District of Columbia, alligator.

Mrs. W. S. Grob, Burke, Virginia, alligator.

Mr. M. E. Hester, Washington, District of Columbia, alligator.

Mr. John Heywood, Gardner, Massachusetts, 10 mallards.

Mr. J. J. Hoffman, Washington, District of Columbia, alligator.

Mrs. Katherine Hunter, Washington, District of Columbia, yellow-headed parrot.

Mrs. J. W. Jenks, Washington, District of Columbia, blue jay.

Dr. Guy W. Latimer, Hyattsville, Maryland, ring-necked pheasant.

Mr. Willis Lillycrop, Washington, District of Columbia, white-throated capuchin.

Mr. T. P. Lovering, Washington, District of Columbia, 2 chicken snakes, a black snake, a southern brown snake, and a brown water snake.

Miss Eleanor Marshall, Washington, District of Columbia, alligator.

Mr. D. W. May, Mayaguez, Porto Rico, Mona Island iguana.

Misses Margaret and Lily Meldahl, Washington, West Virginia, curassow and a red-yellow-and-blue macaw.

Mr. J. C. Meyer, Washington, District of Columbia, fox sparrow.

Mr. Irvin Miller, second officer, steamship *Northland*, Norfolk, Virginia, green heron.

Mr. James Mooney, jr., Washington, District of Columbia, alligator.

Miss Niles, Washington, District of Columbia, alligator.

Mr. William H. Ottemiller, York, Pennsylvania, alligator.

Mrs. M. A. Pitt, Washington, District of Columbia, 3 grass parrakeets.

Mr. T. J. Poole, Washington, District of Columbia, 2 screech owls.

Mrs. J. L. Primm, Washington, District of Columbia, 3 Virginia opossums.

Mr. Louis Rueger, Richmond, Virginia, Mexican puma.

Mr. W. E. Safford, Washington, District of Columbia, gopher turtle.

Mr. E. S. Schmid, Washington, District of Columbia, woodchuck.

Dr. R. W. Shufeldt, Washington, District of Columbia, water snake.

Miss Pearl Smith and Mr. J. C. Lanson, Alcoa, Tennessee, 2 banded rattlesnakes.

Dr. John S. Stearns, Washington, District of Columbia, horned grebe.

Mr. Wilfred Stevens, Wesley Heights, District of Columbia, indigo bunting.

Mr. C. E. Swihart, Fort Barrancas, Florida, horned toad.

Mr. J. H. Taylor, Oxford, Maryland, common skunk.

Mr. Hall Vermillion, Washington, District of Columbia, sparrow hawk.

Mr. Clark Vernon, Washington, District of Columbia, alligator.

Mr. J. W. Weaver, Nashville, Tennessee, common skunk.

Births.—Fifty-two mammals were born, and 41 birds were hatched during the year. The births include 3 bears, 1 hippopotamus, 8 red deer, 1 Bedford deer, 2 elk, 2 mule deer, 2 Virginia deer, 1 fallow deer, 1 axis deer, 2 hog deer, 4 barasingha deer, 3 Japanese deer, 1 black buck, 1 yak, 3 bison, 1 Rocky Mountain sheep, 1 aoudad, 2 guanacos, 3 llamas, 2 great red kangaroos, 1 wallaroo, 6 coypus, and 1 monkey. The birds hatched include Canada geese, ducks, Java sparrows, and peafowl. The hippopotamus is the first one born in the park, and one of very few ever born in America. It is a thrifty male and has attracted great attention.

Exchanges.—In exchange for surplus animals the park received 12 mammals and 62 birds. A drill, a young male sea lion, a pair of scarlet ibises, and numerous ducks for the North American water-fowl lake were obtained in this manner, as well as other species much needed to fill gaps in the collection.

Purchases.—Owing to lack of sufficient funds for the purchase of animals, many desirable species greatly needed in the collection, and offered from time to time, could not be obtained. A total of 26 mammals, 23 birds, and 22 reptiles were received through purchase, mostly small native species at low cost.

Transfers.—Four elk were received from Yellowstone Park through the Department of the Interior, but only two reached Washington in good condition and were saved. These were shipped east with a carload of elk for the State of Virginia, and were obtained with the idea of introducing new blood in the herd maintained at the park. The Biological Survey, of the Department of Agriculture, transferred to the park certain North American mammals, including a mountain lion from Arizona, a dusky marmot from New Mexico, and some mountain beavers from Washington.

Captured in the park.—One bird and one reptile captured within the boundaries of the park, were added to the collection.

Deposited.—Hon. R. M. Barnes, of Lacon, Illinois, sent to the park as a loan a male of the almost extinct trumpeter swan, one of the finest species of North American waterfowl. The park owned a single female of this rare swan and efforts are now being made to mate these surviving birds and preserve the species from extinction. The two swans are quartered in an ideal place, and although they were apparently placed together too late to breed this season, hopes are entertained that by next spring they will be sufficiently familiar with their surroundings to nest. A number of fur-bearing animals from the Bureau of Biological Survey, Department of Agriculture, and some rhesus monkeys from the Hygienic Laboratory were received on temporary deposit.

REMOVALS.

Surplus birds and mammals to the number of 51 were exchanged to other zoological gardens, and 62 animals on deposit were returned to the Bureau of Biological Survey, Department of Agriculture, and to the Hygienic Laboratory. A number of specimens of native species were liberated in the Park and dropped from the list of animals in the collection.

The number of animals lost by death is comparatively small, but some important and valuable animals are included in the list. The death of Dunk, the Indian elephant, was the most notable loss. Dunk was the first animal to be placed in the Zoological Park when the present site was occupied. He was presented to the park by Mr. James E. Cooper, proprietor of the Adam Forepaugh Shows, April 30, 1891, and was then about 25 years old. Over 50 years of age at the time of his death, Dunk had reached the average limit for animals of his kind, for contrary to common belief the longevity of the elephant is not great in proportion to the size of the beast. Others of the more serious losses were a large Galapagos tortoise (*Testudo ephippium*), February 21, from enteritis; the harpy eagle (*Thrasaëtos harpyia*) April 14, from aspergillosis; and a female Manchurian tiger which was mercifully killed as unfit for exhibition June 29. The Galapagos tortoise, with others of his kind, had been in the collection since October 1, 1898. The record for the harpy eagle is a matter of pride for the keepers in the bird department, for this rare bird of prey had been kept in good health for nearly 18 years. He was received May 19, 1890, as a gift from the governor of the State of Amazonas, Brazil, through Commander C. C. Todd, United States Navy. It is believed that the species has never before been kept in any gardens for a similar period.

Post-mortem examinations were made, as usual, by the pathological division of the Bureau of Animal Industry, United States Department of Agriculture. The following list shows the cause of death of animals in each general group. It is believed that the publication of such lists is to be encouraged, as they are of undoubted value to gardens less fortunately provided for up-to-date pathological investigations.

CAUSES OF DEATH.

MAMMALS.

Primates: Gastritis, 1; enteritis, 9; gastroenteritis, 2; no cause found, 1.

Carnivora: Enteritis, 3; gastroenteritis, 7; malnutrition, 1; anemia, 1; peritonitis, 1; internal hemorrhage, 1.

Ungulates: Enteritis, 3; gastroenteritis, 1; pneumonia, 3; congestion of lungs, 1; tuberculosis, 2; uremia, 1; peritonitis, 1; necrosis of jaw, 1; cachexia, 1; malnutrition, 1.

Rodents: Enteritis, 1; gastroenteritis, 1; tuberculosis, 2; anemia, 1.

Marsupials: Enteritis, 1; pneumonia, 1; septicemia, 1.

BIRDS.

Passeriformes: Enteritis, 1.

Coraciiformes: Aspergillosis, 1; no cause found, 2.

Cuculiformes: Gastroenteritis, 1; internal hemorrhage, 1; cause not found, 10.[1]

Charadriiformes: Enteritis, 2; tuberculosis, 3; pneumonia, 2.

Gruiformes: Tuberculosis, 2.

Galliformes: Enteritis, 3; gastroenteritis, 2; quail disease, 22.

Falconiformes: Enteritis, 1; aspergillosis, 3; no cause found, 1.

Anseriformes: Enteritis, 2; tuberculosis, 4; pneumonia, 1; aspergillosis, 2; no cause found, 3.

Ciconiiformes: Enteritis, 5; anemia, 1; internal hemorrhage, 1; fibroma of intestines, 1.

Colymbiformes: Septicemia, 1.

REPTILES.

Testudinata: Enteritis, 1.

Loricata: No cause found, 1.

Serpentes: Enteritis, 1; intestinal necrosis, 1; no cause found, 1.

Thirty-three of the animals lost by death were transferred to the National Museum for mounting. These included all the rarer specimens or those of special scientific importance.

ANIMALS IN THE COLLECTION JUNE 30, 1917.

MAMMALS.

MARSUPIALIA.

Murine opossum (*Marmosa murina*)	1
Virginia opossum (*Didelphis virginiana*)	8
Tasmanian devil (*Sarcophilus harrisi*)	2
Phalanger (*Trichosurus vulpecula*)	2
Dusky phalanger (*Trichosurus fuliginosus*)	2
Nail-tailed wallaby (*Onychogalea frenata*)	1
Brush-tailed rock kangaroo (*Petrogale penicillata*)	2
Great gray kangaroo (*Macropus giganteus*)	2
Red kangaroo (*Macropus rufus*)	5
Wallaroo (*Macropus robustus*)	3
Black-tailed wallaby (*Macropus ualabatus*)	1
Parma wallaby (*Macropus parma*)	1
Wombat (*Phascolomys mitchelli*)	2

CARNIVORA.

Kadiak bear (*Ursus middendorffi*)	1
Alaska Peninsula bear (*Ursus gyas*)	2
Yakutat bear (*Ursus dalli*)	1
Kidder's bear (*Ursus kidderi*)	2
Hybrid bear (*Ursus kidderi-arctos*)	3
European bear (*Ursus arctos*)	2
Himalayan bear (*Ursus thibetanus*)	1
Japanese bear (*Ursus japonicus*)	1
Grizzly bear (*Ursus horribilis*)	3
Black bear (*Ursus americanus*)	3

CARNIVORA—continued.

Kenai black bear (*Ursus americanus perniger*)	2
Cinnamon bear (*Ursus americanus cinnamomum*)	1
Sloth bear (*Melursus ursinus*)	1
Polar bear (*Thalarctos maritimus*)	2
Eskimo dog (*Canis familiaris*)	2
Gray wolf (*Canis nubilus*)	6
Southern wolf (*Canis floridanus*)	1
Woodhouse's wolf (*Canis frustror*)	2
Coyote (*Canis latrans*)	2
Red fox (*Vulpes fulva*)	3
Swift fox (*Vulpes velox*)	1
Gray fox (*Urocyon cinereoargenteus*)	1
Cacomistle (*Bassariscus astutus*)	1
Raccoon (*Procyon lotor*)	8
Gray coatimundi (*Nasua narica*)	1
Kinkajou (*Potos flavus*)	1
Ferret (*Mustela furo*)	1
Mink (*Mustela vison*)	1
Tayra (*Tayra barbara*)	1
Skunk (*Mephitis nigra*)	2
American badger (*Taxidea taxus*)	2
European badger (*Meles meles*)	2
Florida otter (*Lutra canadensis vaga*)	6
African civet (*Viverra civetta*)	1
Genet (*Genetta genetta*)	1
Spotted hyena (*Crocuta crocuta*)	1
African cheetah (*Acinonyx jubatus*)	2
Lion (*Felis leo*)	4
Somaliland lion (*Felis leo somaliensis*)	3
Bengal tiger (*Felis tigris*)	2

[1] Nine lorikeets, while apparently healthy, died suddenly after convulsions. The pathologists have thus far been unable to find the cause.

MAMMALS—continued.

CARNIVORA—continued.

Manchurian tiger (*Felis tigris longipilis*)	1
Leopard (*Felis pardus*)	2
East African leopard (*Felis pardus suahelica*)	1
Jaguar (*Felis onca*)	1
Mexican puma (*Felis azteca*)	2
Mountain lion (*Felis hippolestes*)	4
Canada lynx (*Lynx canadensis*)	3
Bay lynx (*Lynx ruffus*)	6
California lynx (*Lynx californicus*)	1

PINNIPEDIA.

California sea lion (*Zalophus californianus*)	2
Steller's sea lion (*Eumetopias jubata*)	1
Harbor seal (*Phoca vitulina*)	2

RODENTIA.

Patagonian cavy (*Dolichotis patagonica*)	2
Peruvian guinea pig (*Cavia tschudii pallidior*)	6
Guinea pig (*Cavia porcellus*)	20
Coypu (*Myocastor coypus*)	7
Mexican agouti (*Dasyprocta mexicana*)	1
Azara's agouti (*Dasyprocta azarae*)	2
Crested agouti (*Dasyprocta cristata*)	4
Paca (*Cuniculus paca*)	2
Viscacha (*Lagostomus maximus*)	1
Crested porcupine (*Hystrix cristata*)	1
Mountain beaver (*Aplodontia rufa*)	2
Woodchuck (*Marmota monax*)	1
Dusky marmot (*Marmota flaviventris obscura*)	1
Prairie dog (*Cynomys ludovicianus*)	2
Striped spermophile (*Citellus tridecemlineatus*)	1
Albino squirrel (*Sciurus carolinensis*)	1
American beaver (*Castor canadensis*)	2

LAGOMORPHA.

Domestic rabbit (*Oryctolagus cuniculus*)	15

EDENTATA.

Hairy armadillo (*Euphractus villosus*)	2

PRIMATES.

Mongoose lemur (*Lemur mongoz*)	2
Black lemur (*Lemur macaco*)	1
Titi monkey (*Saimiri sciureus*)	2
Gray spider monkey (*Ateles geoffroyi*)	1
White-throated capuchin (*Cebus capucinus*)	3
Brown capuchin (*Cebus fatuellus*)	1
Guinea baboon (*Papio papio*)	3
Chacma (*Papio porcarius*)	1

PRIMATES—continued.

Yellow baboon (*Papio cynocephalus*)	1
Hamadryas baboon (*Papio hamadryas*)	2
Mandrill (*Papio sphinx*)	1
Drill (*Papio leucophaeus*)	1
Moor macaque (*Cynopithecus maurus*)	1
Brown macaque (*Macaca speciosa*)	2
Japanese monkey (*Macaca fuscata*)	2
Pig-tailed monkey (*Macaca nemestrina*)	2
Rhesus monkey (*Macaca rhesus*)	28
Bonnet monkey (*Macaca sinica*)	2
Javan macaque (*Macaca mordax*)	1
Sooty mangabey (*Cercocebus fuliginosus*)	2
Green guenon (*Lasiopyga callitrichus*)	1
Vervet guenon (*Lasiopyga pygerythra*)	3
Mona (*Lasiopyga mona*)	3
Roloway guenon (*Lasiopyga roloway*)	1
Patas monkey (*Erythrocebus patas*)	1
Chimpanzee (*Pan troglodytes*)	1

ARTIODACTYLA.

Collared peccary (*Pecari angulatus*)	1
Wild boar (*Sus scrofa*)	1
Wart hog (*Phacochoerus aethiopicus*)	2
Hippopotamus (*Hippopotamus amphibius*)	3
Bactrian camel (*Camelus bactrianus*)	3
Arabian camel (*Camelus dromedarius*)	3
Guanaco (*Lama huanachus*)	6
Llama (*Lama glama*)	8
Alpaca (*Lama pacos*)	2
Vicuna (*Lama vicugna*)	1
Fallow deer (*Dama dama*)	7
Axis deer (*Axis axis*)	6
Hog deer (*Hyelaphus porcinus*)	7
Sambar (*Rusa unicolor*)	2
Luzon deer (*Rusa philippinus*)	1
Barasingha (*Rucervus duvaucelii*)	13
Japanese deer (*Sika nippon*)	9
Red deer (*Cervus elaphus*)	13
Kashmir deer (*Cervus hanglu*)	6
Bedford deer (*Cervus xanthopygus*)	4
American elk (*Cervus canadensis*)	9
Virginia deer (*Odocoileus virginianus*)	12
Mule deer (*Odocoileus hemionus*)	4
Black-tailed deer (*Odocoileus columbianus*)	3
Blesbok (*Damaliscus albifrons*)	1
White-tailed gnu (*Connochaetes gnu*)	1
Defassa water-buck (*Kobus defassa*)	1
Indian antelope (*Antilope cervicapra*)	6
Springbok (*Antidorcas marsupialis centralis*)	1
Sable antelope (*Ozanna niger*)	1
Nilgai (*Boselaphus tragocamelus*)	2
Congo harnessed antelope (*Tragelaphus gratus*)	2

MAMMALS—continued.

ARTIODACTYLA—continued.

East African eland (*Taurotragus oryx livingstonii*)	3
Tahr (*Hemitragus jemlahicus*)	4
Aoudad (*Ammotragus lervia*)	5
Circassian goat (*Capra hircus*)	2
Rocky Mountain sheep (*Ovis canadensis*)	6
Barbados sheep (*Ovis aries*)	8
Zebu (*Bos indicus*)	2
Anoa (*Anoa depressicornis*)	1
Yak (*Poephagus grunniens*)	4
American bison (*Bison bison*)	18

PERISSODACTYLA.

Brazilian tapir (*Tapirus terrestris*)	4
Mongolian horse (*Equus przewalskii*)	1
Grant's zebra (*Equus burchelli granti*)	1
Grevy's zebra (*Equus grevyi*)	2
Zebra horse, hybrid (*Equus grevyi-caballus*)	1
Zebra ass, hybrid (*Equus grevyi-asinus*)	1

PROBOSCIDEA.

Abyssinian elephant (*Loxodonta africana oxyotis*)	1

BIRDS.

RATITAE.

South African ostrich (*Struthio australis*)	4
Somaliland ostrich (*Struthio molybdophanes*)	1
Rhea (*Rhea americana*)	2
Cassowary (*Casuarius galeatus*)	1
Emu (*Dromiceius novaehollandiae*)	2

CICONIIFORMES.

American white pelican (*Pelecanus erythrorhynchos*)	9
European white pelican (*Pelecanus onocrotalus*)	2
Roseate pelican (*Pelecanus roseus*)	2
Australian pelican (*Pelecanus conspicillatus*)	2
Brown pelican (*Pelecanus occidentalis*)	3
Florida cormorant (*Phalacrocorax auritus floridanus*)	16
White-necked heron (*Ardea cocoi*)	1
Great blue heron (*Ardea herodias*)	1
Snowy egret (*Egretta candidissima*)	3
Green heron (*Butorides virescens*)	1
Black-crowned night heron (*Nycticorax nycticorax naevius*)	14
Boatbill (*Cochlearius cochlearius*)	2
White stork (*Ciconia ciconia*)	5
Black stork (*Ciconia nigra*)	1
Marabou stork (*Leptoptilos dubius*)	1
Sacred ibis (*Threskiornis aethiopicus*)	2
White ibis (*Guara alba*)	11
Scarlet ibis (*Guara rubra*)	2
Roseate spoonbill (*Ajaia ajaja*)	2
European flamingo (*Phoenicopterus roseus*)	1

ANSERIFORMES.

Black-necked screamer (*Chauna torquata*)	3
Horned screamer (*Anhima cornuta*)	1
Mallard (*Anas platyrhynchos*)	10
East Indian black duck (*Anas platyrhynchos var.*)	14
Black duck (*Anas rubripes*)	5

ANSERIFORMES—continued.

European widgeon (*Mareca penelope*)	1
Baldpate (*Mareca americana*)	9
Green-winged teal (*Nettion carolinense*)	11
Blue-winged teal (*Querquedula discors*)	8
Ruddy sheldrake (*Casarca ferruginea*)	1
Pintail (*Dafila acuta*)	9
Wood duck (*Aix sponsa*)	9
Mandarin duck (*Dendronessa galericulata*)	26
Canvas-back (*Marila valisineria*)	1
Lesser scaup duck (*Marila affinis*)	6
Rosy-billed pochard (*Metopiana peposaca*)	1
Snow goose (*Chen hyperboreus*)	3
Blue goose (*Chen caerulescens*)	2
Ross's goose (*Chen rossii*)	1
White-fronted goose (*Anser albifrons*)	4
American white-fronted goose (*Anser albifrons gambeli*)	1
Toulouse goose (*Anser cinereus domesticus*)	2
Bar-headed goose (*Anser indicus*)	2
Canada goose (*Branta canadensis*)	23
Hutchins's goose (*Branta canadensis hutchinsii*)	4
Cackling goose (*Branta canadensis minima*)	2
Barnacle goose (*Branta leucopsis*)	2
Upland goose (*Chloëphaga leucoptera*)	1
Spur-winged goose (*Plectropterus gambensis*)	1
Cape Barren goose (*Cereopsis novaehollandiae*)	2
Wandering tree duck (*Dendrocygna arcuata*)	2
White-faced tree duck (*Dendrocygna viduata*)	3
Black-bellied tree duck (*Dendrocygna autumnalis*)	1
Mute swan (*Cygnus gibbus*)	4
Whistling swan (*Olor columbianus*)	4
Trumpeter swan (*Olor buccinator*)	2
Black swan (*Chenopsis atrata*)	3

BIRDS—continued.

FALCONIFORMES.

South American condor (*Vultur gryphus*)	1
California condor (*Gymnogyps californianus*)	1
Turkey vulture (*Cathartes aura*)	4
Black vulture (*Coragyps urubu*)	2
King vulture (*Sarcoramphus papa*)	2
Secretary bird (*Sagittarius serpentarius*)	1
Griffon vulture (*Gyps fulvus*)	2
Cinereous vulture (*Aegypius monachus*)	2
Lammergeyer (*Gypaëtus barbatus*)	1
Caracara (*Polyborus cheriway*)	5
Yellow-throated caracara (*Ibycter ater*)	1
Crowned hawk eagle (*Spizaëtus coronatus*)	1
Wedge-tailed eagle (*Uroaëtus audax*)	2
Golden eagle (*Aquila chrysaëtos*)	2
Bald eagle (*Haliaeetus leucocephalus*)	15
Alaskan bald eagle (*Haliaeetus leucocephalus alascanus*)	1
Sparrow hawk (*Falco sparverius*)	3

GALLIFORMES.

Mexican curassow (*Crax globicera*)	2
Daubenton's curassow (*Crax daubentoni*)	2
Wild turkey (*Meleagris gallopavo*)	5
Peafowl (*Pavo cristatus*)	35
Peacock pheasant (*Polyplectron bicalcaratum*)	1
Silver pheasant (*Euplocamus nycthemerus*)	1
Natal francolin (*Francolinus natalensis*)	1
Crested francolin (*Francolinus sephaena*)	1
Curaçao crested quail (*Eupsychortyx cristatus*)	2
Bobwhite (*Colinus virginianus*)	5
Scaled quail (*Callipepla squamata*)	2
Gambel's quail (*Lophortyx gambelii*)	1
Valley quail (*Lophortyx californica vallicola*)	1

GRUIFORMES.

American coot (*Fulica americana*)	22
Whooping crane (*Grus americana*)	1
Sandhill crane (*Grus mexicana*)	3
White-necked crane (*Grus leucauchen*)	1
Indian white crane (*Grus leucogeranus*)	1
Lilford's crane (*Grus lilfordi*)	3
Australian crane (*Grus rubicunda*)	1
Demoiselle crane (*Anthropoides virgo*)	7

GRUIFORMES—continued.

Crowned crane (*Balearica pavonina*)	2
Cariama (*Cariama cristata*)	1

CHARADRIIFORMES.

Great black-backed gull (*Larus marinus*)	1
Herring gull (*Larus argentatus*)	1
Laughing gull (*Larus atricilla*)	2
Australian crested pigeon (*Ocyphaps lophotes*)	14
Wonga-wonga pigeon (*Leucosarcia picata*)	10
Speckled pigeon (*Columba phaeonota*)	1
Snow pigeon (*Columba leuconota*)	2
White-crowned pigeon (*Patagioenas leucocephala*)	1
Band-tailed pigeon (*Chloroenas fasciata*)	4
Red-billed pigeon (*Chloroenas flavirostris*)	4
White-winged dove (*Melopelia asiatica*)	1
Mourning dove (*Zenaidura macroura*)	10
Peaceful dove (*Geopelia tranquilla*)	2
Zebra dove (*Geopelia striata*)	10
Cape masked dove (*Oena capensis*)	3
Inca dove (*Scardafella inca*)	3
Blue-headed quail-dove (*Starnoenas cyanocephala*)	2
Collared turtle-dove (*Streptopelia risoria*)	20

CUCULIFORMES.

White-crested touraco (*Turacus corythaix*)	1
Grass parrakeet (*Melopsittacus undulatus*)	8
Black-tailed parrakeet (*Polytelis melanura*)	1
Banded parakeet (*Palaeornis fasciata*)	1
Lesser vasa parrot (*Coracopsis nigra*)	1
Gray parrot (*Psittacus erithacus*)	1
Cuban parrot (*Amazona leucocephala*)	1
Porto Rican parrot (*Amazona vittata*)	1
Yellow-winged parrot (*Amazona barbadensis*)	2
Festive parrot (*Amazona festiva*)	1
Yellow-fronted parrot (*Amazona ochrocephala*)	2
Yellow-naped parrot (*Amazona auropalliata*)	2
Yellow-headed parrot (*Amazona oratrix*)	4
Quaker parrot (*Myiopsitta monachus*)	1
Red-and-blue macaw (*Ara chloroptera*)	2
Red-and-yellow-and-blue macaw (*Ara macao*)	7
Yellow-and-blue macaw (*Ara ararauna*)	1

BIRDS—continued.

CACATUIFORMES—continued.

Sulphur-crested cockatoo (*Cacatua galerita*)	3
Great red-crested cockatoo (*Cacatua moluccensis*)	1
White cockatoo (*Cacatua alba*)	8
Leadbeater's cockatoo (*Cacatua leadbeateri*)	1
Bare-eyed cockatoo (*Cacatua gymnopis*)	3
Roseate cockatoo (*Cacatua roseicapilla*)	12
Scaly-breasted lorikeet (*Psitteuteles chlorolepidotus*)	1

CORACIIFORMES.

Giant kingfisher (*Dacelo gigas*)	2
Concave-casqued hornbill (*Dichoceros bicornis*)	1
Barred owl (*Strix varia*)	6
Screech owl (*Otus asio*)	3
Great horned owl (*Bubo virginianus*)	14

PASSERIFORMES.

Yellow tyrant (*Pitangus sulphuratus*)	1
Japanese robin (*Liothrix luteus*)	4
Laughing thrush (*Garrulax leucolophus*)	2
Mockingbird (*Mimus polyglottos*)	1
Brown thrasher (*Toxostoma rufum*)	1
Australian gray jumper (*Struthidea cinerea*)	1
Red-billed magpie (*Urocissa occipitalis*)	1

PASSERIFORMES—continued.

American magpie (*Pica pica hudsonia*)	3
Blue jay (*Cyanocitta cristata*)	2
American crow (*Corvus brachyrhynchos*)	1
Australian crow (*Corvus coronoides*)	1
European raven (*Corvus corax*)	1
Glossy starling (*Lamprotornis caudatus*)	1
Malabar starling (*Spodiopsar malabaricus*)	1
Napoleon weaver (*Pyromelana afra*)	2
Crimson-crowned weaver (*Pyromelana flammiceps*)	2
Madagascar weaver (*Foudia madagascariensis*)	3
Paradise weaver (*Steganura paradisea*)	5
Cut-throat finch (*Amadina fasciata*)	1
Black-faced Gouldian finch (*Poephila gouldiae*)	1
Black-headed finch (*Munia atricapilla*)	4
Three-colored finch (*Munia malacca*)	1
Nutmeg finch (*Munia punctularia*)	2
Java sparrow (*Munia oryzivora*)	13
White Java sparrow (*Munia oryzivora*)	5
Cowbird (*Molothrus ater*)	1
Fox sparrow (*Passerella iliaca*)	1
Nonpareil (*Passerina ciris*)	1
Saffron finch (*Sicalis flaveola*)	12
Canary (*Serinus canarius*)	4
Green singing finch (*Serinus icterus*)	3
Red-crested cardinal (*Paroaria cucullata*)	2
Cardinal (*Cardinalis cardinalis*)	6

REPTILES.

Gopher tortoise (*Gopherus polyphemus*)	1
Duncan Island tortoise (*Testudo ephippium*)	1
Albemarle Island tortoise (*Testudo vicina*)	1
Alligator (*Alligator mississippiensis*)	30
Mona Island iguana (*Cyclura stejnegeri*)	1
Gila monster (*Heloderma suspectum*)	7
Horned toad (*Phrynosoma cornutum*)	1
Rock python (*Python molurus*)	3
Anaconda (*Eunectes murinus*)	1
Boa constrictor (*Constrictor constrictor*)	3
Water snake (*Natrix sipedon*)	2
Black snake (*Coluber constrictor*)	2
Coach-whip snake (*Coluber flagellum*)	1
Chicken snake (*Elaphe obsoleta quadrivittata*)	2

STATEMENT OF THE COLLECTION.

ACCESSIONS DURING THE YEAR.

Presented:		
Mammals	28	
Birds	44	
Reptiles	27	
		99
Born and hatched in the National Zoological Park:		
Mammals	52	
Birds	41	
		93
Received in exchange:		
Mammals	12	
Birds	62	
		74
Purchased:		
Mammals	26	
Birds	23	
Reptiles	22	
		71
Transferred from other Government departments:		
Mammals	5	
		5
Captured in National Zoological Park:		
Birds	1	
Reptiles	1	
		2
Deposited:		
Mammals	52	
Birds	1	
		53
Total accessions		397

SUMMARY.

Animals on hand July 1, 1916	1,383
Accessions during the year	397
	1,780
Deduct loss (by exchange, death, return of animals, and animals liberated)	557
On hand June 30, 1917	1,223

Class	Species.	Individuals.
Mammals	139	694
Birds	182	489
Reptiles	14	40
Total	353	1,223

VISITORS.

The number of visitors to the park during the year, as determined by count and estimate, was 1,106,800, a daily average of 3,032. The greatest number in any one month was 171,400, in April, 1917, an average per day of 5,713. The attendance by months was as follows:

1916: July, 78,800; August, 80,500; September, 122,550; October, 92,200; November, 43,250; December, 44,625.

1917: January, 37,750; February, 53,675; March, 106,400; April, 171,400; May, 110,550; June, 161,100.

Excepting 1910, this was the largest attendance in the history of the park. The number of visitors was only 50,310 less than in 1910, and doubtless would have exceeded that record year but for the unseasonable weather on Easter Monday.

One hundred and fifty-three schools and classes visited the park, with a total of 8,492 individuals. In addition to the local schools and those from near-by States, these included schools from Alabama, Arkansas, Massachusetts, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, and Vermont. A number of officials from other zoological gardens visited the park.

The exceptionally favorable weather made the skating pond an attractive feature during the past winter and for a much longer period than usual. The ice was kept clean of snow throughout the season and the appreciation of the public would seem to warrant the construction of additional lakes to be used for exhibits of waterfowl during the summer and skating in winter.

IMPROVEMENTS.

The hospital and laboratory, which has been mentioned in the reports for the last two years, is still unfinished, but a considerable amount of work was done on the interior cages so that the building now lacks only the necessary outside yards and the laboratory equipment. The hospital cages are designed for the care and special comfort of indisposed or quarantined animals, and accommodations are provided for two mammals of lion size, three of leopard size, three large ruminants, and a number of smaller animals. In addition, there is a large, well lighted, central room for laboratory use. The completion of this building will greatly facilitate the work of the pathologists from the Department of Agriculture who visit the park.

The largest waterfowl lake, in the southeastern part of the park, was enlarged and reconstructed to provide safe and retired breeding and resting places for the birds. It had formerly been inclosed by a fence of ordinary poultry wire without special protection from predacious animals, and there had been frequent loss from the depredations of rats and the smaller native carnivores. In order to increase sufficiently the land area it was necessary to construct a stone wall along Rock Creek at the rear of the inclosure. By lowering the grade of the hill bordering the lake, sufficient earth was produced to fill up to the level of the wall on the inner side. A rat-proof fence was woven in the machine shop and further provided with guards against cats and raccoons. The level of the water was raised about 12 inches, greatly increasing the size of the lake, and the new fence was constructed on a concrete coping considerably outside the former

boundary. Numerous shrubs, small trees, canes, and grasses were planted to supplement the fine growth of larger trees already on the area. Visitors walk along one side of the lake only and as the thick vegetation virtually hides the fence on the opposite side at all points the effect is that of a wilderness breeding lake for ducks and geese. As completed, the inclosure provides almost natural conditions for the waterfowl of numerous species and forms a very attractive exhibit. It has been given over entirely to North American species, and it is hoped that a large representation of the ducks, geese, and other aquatic birds commonly associated with them native to our continent may be kept here. On June 30, no less than 136 North American waterfowl, of 24 species, were to be seen on the lake. The natural surroundings and the fact that only American species are shown here makes this waterfowl lake of special interest to school classes, sportsmen, and bird lovers, and it has become one of the popular features of the park. A cement walk was extended from the bridge near the Harvard Street entrance along the south side of the road to the crossroads, to connect with the cinder path bordering the lake.

The work of grading and filling around the old buffalo house and the remodeling of the building for other uses, which was commenced last year, has been completed. As reconstructed the building makes an ideal shelter of pleasing design and furnishes house space for the animals occupying the six large paddocks that surround it. The Canadian Rocky Mountain sheep, the elands, and the Kashmir deer are provided for in this group of yards.

An outdoor cage and shelter, summer quarters for the chimpanzee, were built near the north entrance to the lion house. This provides not only for the better health of this interesting trained ape, but makes it possible for larger crowds to gather about at the time his meals are served.

New paddocks were provided for ungulate mammals on the piece of ground recently leveled by grading northwest of the llama yards. Much-needed repairs were made on the wolf dens and to the lion house roof.

A considerable portion of the pasture land near the office was plowed as an addition to the garden, in an effort to decrease the cost of feed for the animals. For the same reason horseflesh has been substituted for beef as food for the carnivorous animals, with the prospect of saving at least $6,000 on this item alone during the next fiscal year. A portion of the nursery was fenced and breeding pens for quail and other game birds were installed within the inclosure. It is hoped that most of the quail of various species needed for park purposes may be reared in this place and that important experiments in the breeding of game birds may at the same time be conducted without additional expense.

THE PARK AS A BIRD SANCTUARY.

The entire 169 acres of the National Zoological Park constitutes a carefully preserved sanctuary for native wild birds. Every effort is being made to increase the bird population within this area and to give better protection to the resident species. During the past year over 100 nesting boxes were provided for those species which commonly nest in holes in trees. These were made in the carpenter shop at odd times during the winter months from trunks and limbs of fallen trees with the bark in place. Attached to trees of the same kind or with bark of the same color these nesting boxes are much less conspicuous and unsightly in the park trees than square boxes made from planed boards. Many of the boxes were occupied during the summer by bluebirds, chickadees, nuthatches, wrens, and flickers, and additional nests will be provided from year to year. During the colder months food is provided for the winter residents in various parts of the park.

Of all the native wild birds within the park perhaps none attract so much attention as the turkey vultures, or "buzzards," which congregate here in great number during the fall and winter months. Food, at practically no expense, is provided for the vultures, and they become very tame and confiding. Many visitors from the Northern States, to whom the birds are a novel sight, greatly admire the graceful flight of these interesting creatures. During the summer months the vultures scatter out over the surrounding country to nest, and only a few appear within the boundaries of the park, but the security afforded for winter roosts brings them back in great numbers with the approach of autumn.

Bobwhite quail appear to be increasing in numbers within the park and are now fairly abundant. A considerable number of these birds much help stock the surrounding country from year to year.

Numerous bird classes from the schools and parties of Audubon Society members find the wilder parts of the park ideal grounds for observation of the birds.

ALTERATION OF WESTERN BOUNDARY.

It again appears desirable to recapitulate for future reference the various stages through which the matter of the adjustment of the western boundary, near the Connecticut Avenue entrance, has passed.

The following appropriation was made by the act approved June 23, 1913:

Readjustment of boundaries: For acquiring, by condemnation, all the lots, pieces, or parcels of land, other than the one hereinafter excepted, that lie between the present western boundary of the National Zoological Park and Connecticut Avenue from Cathedral Avenue to Klingle Road, $107,200, or such portion thereof as may be necessary, said land when acquired, together with

the included highways, to be added to and become a part of the National Zoological Park. The proceedings for the condemnation of said land shall be instituted by the Secretary of the Treasury under and in accordance with the terms and provisions of subchapter one of chapter fifteen of the Code of Law for the District of Columbia.

As the act required that the proceedings be instituted by the Secretary of the Treasury, the attention of that official was called to the matter in a letter from the Secretary of the Smithsonian Institution, dated June 28, 1913. A special survey and plat of the land required was necessary, but this plat was not forwarded to the Department of Justice until November 5, 1913. Other delays ensued: the title of the various owners of the land had to be investigated, and it was not until March 11, 1914, that the district court ordered a jury to be summoned. A hearing was set for April 10, 1914, and a final hearing of the case was heard by the jury on July 2 following. The verdict of the jury was not filed until December 11, 1914. The hearing of objections to the verdict much delayed a final conclusion, especially as the time of the court was almost wholly occupied by a contest in an important will case. It was not until June 28, 1915, over two years from the passage of the appropriation act, that the court confirmed the verdict as regards the awards for damages for the land to be taken. The benefits assessed against the neighboring property were set aside by this and by a subsequent decision of January 28, 1916. The decree of the court fixed the amount required for the purchase of the land at $104,438.08. The cost of the proceedings for condemnation was $2,203.35.

The great delay caused by these legal proceedings occasioned another complication. The appropriation made by the act of June 23, 1913, was not a continuing one, but lapsed at the end of one year. Consequently after June 30, 1915, there was nothing available to defray the purchase of the land.

An item for an additional appropriation and for a reappropriation of the original sum appropriated by the act of June 23, 1913, was submitted to the first and second sessions of the Sixty-fourth Congress, but was not favorably considered.

It is greatly to be regretted that this appropriation failed, as it is exceedingly desirable that the land in question be obtained for park purposes before it is too late. A frontage on Connecticut Avenue at this point is most important, because the principal entrance to the park will probably be here for all time, and it is essential that the control of the land be in the hands of park authorities.

IMPORTANT NEEDS.

Grading and filling.—The work of grading and filling, commenced last year, should be continued. The further cutting away of the

irregular hill in the center of the western part of the park and the filling in of a nearby ravine will level nearly 70,000 square feet of ground which is now of little use and make available about 25,000 square feet of ground at the ravine, besides straightening out the automobile road at this point. More inclosures are seriously needed for deer and similar animals, and this grading would provide for a number of these yards on flat ground.

Public-comfort building and restaurant.—The need of a suitable structure for a rest house and refreshment room is strongly felt. This rest house should provide toilet facilities for both women and men. It is probably true that the present restaurant occasions more unfavorable comment from visitors than any other one feature in the park. It is only a rude wooden platform with cover, but with open sides; the kitchen and other facilities are inadequate, and the entire structure is in a bad state of repair.

Roads, bridle paths, and automobile parking.—The question of providing space for the parking of automobiles near the main buildings in the center of the park is becoming serious. The available space is entirely insufficient on nearly every Sunday and on all holidays. In order to provide suitable accommodations for the constantly increasing number of cars it will be necessary to make some change in the roads and lawns at the central point. It will be necessary to make extensive repairs to the roads during the coming year, which will involve a considerable expenditure. The roads need repair now, but under the stringent economy that is compelled during 1918 it will not be possible to make even the repairs already needed, nor to provide proper upkeep of the roads. The greatly increased auto traffic (sometimes 2,500 cars in a day) makes necessary each year greater expenditures to keep the roads in order. Some change should be made in the bridle paths in order that equestrians would not be forced to use the bridge and the main road from the Harvard Street gate to the crossroads. Numerous complaints have been made as to the danger at these points, not only to children, but to the riders themselves. The bridle path could, at some expense, be carried up the west side of the creek from the crossroads, and a ford constructed to connect with the bridle path on the east side of the creek.

Outdoor dens for carnivorous mammals.—Recent experiments have shown that many kinds of animals usually kept in heated houses are much better off in outdoor yards, with warm, but unheated sleeping quarters. Such accommodations should be provided for the Siberian tiger, some of the lions, and other animals now occupying quarters in crowded heated houses. The health of these animals would unquestionably be improved and their lives prolonged under such conditions, and the space they now occupy in heated houses would become available for other animals really needing such accommodations.

A series of outdoor, unheated cages and shelters should also be provided to replace the series of unsightly old wooden cages along the hilltop north of the bird house.

Additional ponds for waterfowl.—Additional lakes to be used for waterfowl in summer and for skating in winter could be provided at comparatively small expense both in the open flat near the Harvard Street entrance and near the pelican pond across the road. Exhibits of waterfowl are very popular and instructive, and the skating privilege is much appreciated by the public in winter.

Aviary building.—The park reports have for a number of years urged the appropriation of funds for a new bird house. That such a structure is badly needed is apparent. The building now used for the birds was erected in the cheapest manner possible for temporary use and is now in a bad state of repair. The collection is an important one, and a suitable bird house would without doubt prove one of the most attractive and instructive features of the park.

Reptile house.—A properly constructed reptile house would, it is certain, prove almost as attractive to the public as a bird house. The comparatively small collection of reptiles now kept in crowded quarters in the lion house is very popular.

The most urgent need of the park is a substantial increase in the general appropriation. When the amount provided was raised to the present figure, seven years ago, it was recognized that there was necessity for a considerable sum above the cost of actual maintenance, in order that improvements could be made and the grounds and buildings be kept in a good state of repair. Owing to the steady advance in the price of supplies and to the additional expense necessitated by the constantly increasing number of visitors, the point has now been reached where the entire appropriation does not cover actual maintenance expenses. It is only by rigid economy, and by the elimination of some things really necessary, that the cost of operation can be kept within the amount.

Respectfully submitted.

N. Hollister,
Superintendent.

Dr. Charles D. Walcott,
Secretary of the Smithsonian Institution.

Appendix 5.

REPORT OF THE ASTROPHYSICAL OBSERVATORY.

Sir: I have the honor to present the following report on the operations of the Smithsonian Astrophysical Observatory for the year ending June 30, 1917.

EQUIPMENT.

The equipment of the observatory is as follows:

(*a*) At Washington there is an inclosure of about 16,000 square feet, containing five small frame buildings used for observing and computing purposes, three movable frame shelters covering several out-of-door pieces of apparatus, and also one small brick building containing a storage battery and electrical distribution apparatus.

(*b*) At Mount Wilson, California, upon a leased plat of ground 100 feet square, in horizontal projection, are located a one-story cement observing structure, designed especially for solar-constant measurements, and also a little frame cottage, 21 feet by 25 feet, for observer's quarters. Upon the observing shelter at Mount Wilson there is a tower 40 feet high above the 12-foot piers which had been prepared in the original construction of the building. This tower is equipped with a tower telescope for use when observing (with the spectrobolometer) the distribution of radiation over the sun's disk.

During the year apparatus for research has been purchased or constructed at the observatory shop. The value of these additions to the instrumental equipment is estimated at $1,000.

WORK OF THE YEAR.

1. AT WASHINGTON.

Three copies of the pyranometer, our new instrument for measuring sky radiation, have been prepared by the Institution, respectively, for the United States Weather Bureau, the University of Wisconsin, and for the proposed expedition to South America mentioned in my report for 1916. These instruments were finished and standardized by Mr. Aldrich. The tests made led to long investigations and improvements, which greatly increased the sensitiveness of the pyranometer. All three instruments are now in use and, so far as known, with satisfaction.

Two silver-disk pyrheliometers were standardized for the proposed South American expedition.

Considerable work was done on the apparatus mentioned last year, designed to measure the constant of the fourth power radiation formula. Owing to trouble found in maintaining a vacuum in the apparatus no actual determinations were made.

Much attention was devoted to the preparation of the equipment of a solar-constant expedition for South America. The purpose of the expedition, as stated last year, is by cooperation with Mount Wilson to secure daily values as far as possible throughout the year for several years, and thus to investigate the influence of solar variation on terrestrial temperature. Many improved devices were invented and constructed for the expedition. Among them is a new vacuum bolometer of very high sensitiveness and in every way exemplary behavior. This instrument is constructed in such a way as to be sealed off when highly exhausted, like an X-ray tube. Having no cocks or windows it requires no further attention to maintain a vacuum indefinitely. The construction of the sensitive strip follows the indications of mathematical analysis covering the whole theory of the bolometer, so that a maximum sensitiveness is obtained. A similar instrument was prepared also for Mount Wilson work. The high sensitiveness of the new bolometer is indicated by the statement that when used with the same spectroscope and galvanometer employed in our Algerian expedition of 1912 more than tenfold deflections on the solar spectrum were observed with similar conditions.

Another new instrument is a special machine designed to aid in reducing spectrobolometry, in solar-constant work. Heretofore we have plotted, on large cross-section paper, logarithms of observed radiation against the air masses traversed by the solar beam. Nearly 40 such plots, each of six points, are required to represent a morning's spectrobolometry. The plotted points fall in approximately straight lines, whose projection to the zero of air mass yields logarithms of intensities as they would be observed outside our atmosphere. The inclinations of the representative straight lines give the logarithms of the atmospheric transmission coefficients. What I desire to point out is that the process requires taking out about 300 logarithms, besides plotting and extrapolating.

In the new instrument as shown in the illustration six 10-inch slide rules are arranged to be set at chosen places and at right angles to a horizontal linear scale of air masses. The observations are set up by reading the crossline of the sliders against the central movable slide-rule scales, these latter being set with respect to the fixed scales on the sides so as to apply a small correction for sensitiveness of the bolometric apparatus. A stretched wire is then adjusted to fit the six points as thus plotted. On another slide rule fixed at zero air

mass one reading of the crossing point of the wire over the fixed scale gives the intensity as it would be outside the atmosphere, and a second reading on the movable scale gives the atmosphere transmission coefficient. No logarithms or computing are required.

The equipment of the expedition was all boxed ready for shipment to South America when circumstances connected with the war with Germany led to a postponement. Under these circumstances it was deemed best to send the expedition to Hump Mountain in North Carolina, a station at 4,800 feet elevation, where it is now located. This location was chosen with a view to its being at a great distance from Mount Wilson, in a region where Weather Bureau observers reported uncommonly little cloudiness, and easily accessible from the railroad and from Washington.

The expedition with over 3 tons of equipment went forward in May, 1917. It is in charge of Mr. A. F. Moore, who is assisted by Mr. L. H. Abbot. Two small frame buildings were erected for the observing and living quarters. The apparatus was set up and adjusted by Messrs. C. G. Abbot, L. B. Aldrich, and A. F. Moore, and gotten ready for observing about June 15. Unfortunately the most cloudy and rainy summer in the recollection of old residents had been experienced up to August 1. Otherwise, everything is highly favorable to excellent solar-constant work. If war conditions warrant, the Institution still hopes to send the expedition to South America later, where a station is selected at which 300 cloudless forenoons for observing per year are to be expected.

Before leaving this subject I desire to call attention to the remarkable paper by Dr. Helm Clayton (Smithsonian Misc. Coll., vol. 68, No. 3) on the "Effect of Short Period Variations of Solar Radiation on the Earth's Atmosphere." Doctor Clayton shows by the mathematical method of correlations, free from all influence of personal judgment, that variations of solar radiation observed by us at Mount Wilson in 1913 and 1914 were reflected in variations of terrestrial temperatures all over the world. The correlations were positive in and near the Tropics, negative in Temperate Zones, and positive near the poles. A lag of from 1 to 5 days occurred, the lag being less for Tropical Zones. The barometric pressure also appeared to join in the correlations. By an ingenious application of his method Doctor Clayton shows that the short interval fluctuations of solar radiation are not altogether without periodicity, for the changes tend to repeat themselves after 11 and 22 days, respectively. The same tendency is found in the temperature records of Buenos Aires. We are now engaged in testing this conclusion by computations for other years.

Computations of Mount Wilson solar observations went on in the hands of Miss Graves as usual at Washington, and the computing is practically up to date.

Mr. Fowle's research on the effect of water vapor and carbon dioxide of the atmosphere to absorb long-wave rays, such as the earth sends out, is now ready for publication. Many of the best observations were made by him during the past year. Some observations made in February, 1917, at a time when the humidity of the atmosphere was very small, proved of special value. Opportunity was taken of using some of the apparatus prepared for the South American expedition to aid in making bolographic observations on the solar spectrum at very great wave lengths, reaching to 17 microns. By means of the spectrobolometer prepared for South America it was possible to determine accurately the quantities of water vapor in the path of the solar beam.

Certain conclusions stated in Volume II of the Annals of the Astrophysical Observatory may now be corrected to correspond with the new information. We stated:

We can by no means admit that the radiation from the solid and liquid surface of the earth passes unhindered to space. * * * The clouds, whose average presence includes 52 per cent of the time, * * * are even more efficient screens to the radiation of the earth than they are to the radiation of the sun, so during 52 per cent of the time we may regard the radiation of the solid and liquid earth to space as zero. During the remainder of the time water vapor presents almost as effective a screen * * *. From the combined work of Rubens and Aschkinass, Langley, Keeler and Very, and Nichols, we * * * conclude that a tenth part of the average amount of water vapor in the vertical column of atmosphere above sea level is enough to absorb more than half of the radiation of the earth to space, and it is highly probable that, considering the greater air mass attending the oblique passage of many of the rays to space, nine-tenths of the radiation of the solid and liquid surface of the earth is absorbed by the water vapor of the atmosphere even on clear days. On cloudy days none is transmitted, so that the average escape of radiation from the earth's surface to space probably does not exceed 5 per cent.

Some writers have attributed a large share of the absorption of the atmosphere to the carbonic-acid gas which it contains, but * * * in atmospheric conditions the absorption of carbonic-acid gas in the spectrum of the earth appears to be confined to two bands extending from wave lengths 3.6 to 5.4μ, and from 12.0 to 16.0μ, respectively. In these bands its absorption is nearly total from 4.0 to 4.8μ and from 14.0 to 15.0μ even when carbonic-acid gas is present in much less quantities than the atmosphere contains. * * * In the absence of water vapor the total absorption possible by carbonic-acid gas would be 14 per cent. In all the lower regions of the atmosphere, however, water vapor is present in such quantities as almost completely to extinguish the radiation of the earth's surface in these two special regions. * * * It therefore does not appear possible that the presence or absence, or increase or decrease, of the carbonic acid contents of the air is likely to appreciably influence the temperature of the earth's surface.

It seems certain, in view of what has been said that the earth's solid and liquid surfaces, and the lower parts of the atmosphere, contribute directly almost nothing to the amount of radiation which the earth as a planet sends to space. The earth's surface and the lower atmosphere, of course, exchange radiation together, and by this process and by convection the heat of these

> regions ascends toward space. But convection grows less and less as the air becomes rarer, and must at length cease to be an appreciable factor. It is the water vapor and carbonic-acid gas far above the earth's surface, where the absorption of the rays by the water vapor and carbonic-acid gas lying still higher becomes small, that form the true radiating surface of the earth considered as a planet. * * * With the scanty material at hand, and in consideration of the distribution of water vapor in the free air, it seems safe to put the effective position of the radiating surface at fully 4,000 meters above sea level * * * at a probable mean temperature of 263° absolute centigrade or —10° centigrade.

Some writers have misinterpreted these remarks and understood us as supposing that there is a special layer at 4,000 meters elevation above sea level which prevents radiation escaping from below and whose own radiation passes unhindered to space. Our meaning was quite different. Every layer from sea level to the limit of the atmosphere contributes something to the total radiation output of the earth. But, because of the great absorption of superposed water vapor and clouds, the lower solid and liquid and atmospheric layers contribute little, while because of their dryness the higher atmospheric layers contribute little. Roughly estimating the various factors, we concluded that the center of activity of the radiation of the earth as a planet could be set at about 4,000 meters elevation.

How far are these conclusions now to be altered? As to the effect of cloudiness, not at all. As to water vapor Mr. Fowle finds the following results on the percentages of absorption of rays from a perfect radiator at the earth's mean temperature in atmospheric columns containing besides carbon dioxide sufficient to produce maximum absorption, water vapor which if precipitated would produce certain depths of liquid water:

Ppt. water cm.	0.003	0.03	0.3	3.0
Absorption	40	57	66	75

In order to apply these data I give figures for the average quantities of terrestrial water vapor which, according to Hann, exist in vertical columns from sea level to the limit of the atmosphere over different zones of the earth.

Latitude	0–20°	20°–30°	30°–40°	40°–50°	50°–60°	60°–90°
Ppt. water cm.	4.3	3.1	2.2	1.6	1.0	0.6

From these figures it may be seen that the statement, "a tenth part of the average amount of water vapor in the vertical column above sea level is enough to absorb more than half of the radiation of the earth to space," is confirmed. But the conclusion therefrom that "nine-tenths of the radiation of the solid and liquid surface of the earth is absorbed by the water vapor of the atmosphere on clear days" is not confirmed. Mr. Fowle has computed the absorption of the atmosphere in a state of humidity corresponding to 1.0 cm. ppt. water, and finds it 72 per cent. Considering that the ppt. water in a vertical

column over most of the earth exceeds 3.0 cm., it now seems probable that the proper figure should be eight-tenths instead of nine-tenths.

As regards the absorption of carbonic-acid gas Mr. Fowle finds that one-fortieth part of the amount of this gas found in a vertical atmospheric column produces the maximum possible effect. This does not lead to any modification of our conclusions as to the effect of atmospheric carbonic-acid gas as stated above.

With ordinary humidity, at sea level a layer of air 10 meters long, according to Fowle, will absorb 50 per cent of the radiation of a perfect radiator at terrestrial temperatures. Similarly the layer of air above 11 kilometers, or 6 miles, altitude contains enough water vapor to absorb 50 per cent of such radiation.

In view of what has been said and remembering the presence of clouds, only about one-tenth of the radiation of the solid and liquid surface of the earth escapes directly to space. The atmosphere above 11 kilometers apparently contributes more than half of the radiation of the earth viewed as a planet and prevents half of the radiation of lower layers from escaping. Nearly the entire output of radiation of the earth to space, certainly more than three-fourths, arises from the atmosphere and its clouds as its source. The "effective radiating layer," meaning a layer which if perfectly radiating to space would equal in radiation the actual earth viewed as a planet, may still be thought of as at several kilometers altitude and at a temperature well below freezing.

The subject of atmospheric absorption is so difficult both theoretically and experimentally that much more investigation ought still to be done on it. Mr. Fowle's long experience has well fitted him for making further advances. It is hoped to put at his disposal soon the necessary means to make new researches. These include bolometric apparatus of greatly increased sensitiveness, such as recent studies now enable us to construct. The one obstacle to complete success which now seems insuperable is the lack of any means to form an intense unabsorbed spectrum free from stray light, extending from 15 to 50 microns in wave length.

2. AT MOUNT WILSON.

The expedition of 1916 continued solar-constant and other observations at Mount Wilson until late in October. The expedition was renewed late in June, 1917. Improvements in the supply of electricity and water to the station were completed in June, 1917.

In 1916 many observations of the sky by day and by night were made at Mount Wilson with the pyranometer. The plan was followed from August to October of measuring with this instrument the total solar radiation at a fixed zenith distance of the sun, and almost

simultaneously the total sky radiation over a fixed small area immediately surrounding the sun. It seems probable that as the brightness of the sky depends on the prevailing humidity and dust, and as the radiation of the sun is diminished by presence of humidity and dust, a method of combination of the two measurements may be found, adapted to give approximately the solar constant. When computations are further advanced the matter will be tested.

Restandardization of secondary pyrheliometers in 1916 against our standard water-flow pyrheliometer indicated no change in their constants.

A vacuum bolometer was employed during a large part of the observing season. The sensitiveness was so much greater that considerable improvement in the work on the investigation of the distribution of radiation over the sun's disk was possible.

Redeterminations were made with great care on the form of distribution of the solar energy curve outside the atmosphere. New mirrors of stellite, a very hard nontarnishing alloy, were substituted for the silvered mirrors of the spectrobolometer. It is hoped that the work of 1916 will indicate conclusively how the sun's variations affect the distribution of energy in the solar spectrum.

SUMMARY.

Preparation of apparatus and equipment for a new solar-constant station of the Smithsonian Institution, now located at Hump Mountain, North Carolina, led to valuable improvements in the bolometer and the pyranometer, and to the invention and construction of a new instrument for avoiding computation in reduction of spectrobolometric observations.

A long research on the transmission of long-wave rays by atmospheric columns of known humidity and carbon dioxide contents, has been completed and prepared for publication by Mr. Fowle. In expeditions to Mount Wilson the observation of the amount and distribution of solar radiation has been continued. In cooperation with the new station above mentioned it is hoped to obtain much more complete records of the variation of the sun, now shown by Clayton to be of great meteorological significance.

Respectfully submitted.

C. G. Abbot,
Director Astrophysical Observatory.

Dr. Charles D. Walcott,
Secretary of the Smithsonian Institution.

APPENDIX 6.

REPORT ON THE LIBRARY.

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution during the fiscal year ending June 30, 1917:

The Smithsonian library was founded with the definite plan that it should contain publications of the scientific institutions and learned societies of the world, together with a collection of periodicals and publications of a scientific nature. The most important function contemplated was that of reference for research in the broadest sense, and in this connection a complete collection of the catalogues of the libraries of the world was also contemplated. This policy has been continued with the result that the vast series of scientific publications in the Smithsonian library, now numbering a half million of titles, has been brought together.

As early as 1865 Secretary Henry realized that it would not be possible to adequately care for the entire collection in the Smithsonian building, even if the entire building were devoted to the purpose; and a special act of Congress authorized the Library of Congress to assume the care of the main library of the Smithsonian Institution, the Institution to retain ownership of the publications and to have the same use of the books as if they were in its own building, and in addition to have the same privileges in the use of the Library of Congress as Members of Congress. While the main collection is in the Library of Congress, there are smaller collections here in the Institution, i. e., the books for office reference, dictionaries, encyclopedias, etc., the Government branch libraries of the Astrophysical Observatory, Bureau of American Ethnology, and the United States National Museum. All of these are confined to special publications relating to the subjects covered by the bureaus, and supplement rather than duplicate books in other libraries.

The library of the Smithsonian Institution is augmented in two ways, i. e., by gift, and through the exchange of the Institution's publications for those of similar institutions.

JOHN DONNELL SMITH LIBRARY.

In 1905 Dr. John Donnell Smith, of Baltimore, Maryland, offered to the Smithsonian Institution his botanical library, consisting of

over 1,500 volumes, to accompany his herbarium, to which it is closely related. The proposed gift was the most valuable of its kind that had been offered to the Institution, and it will be of great assistance in the development of botanical research in the Museum. The conditions were that Doctor Smith should retain possession of the books as long as he desired, and that when his library should come to the Institution it should be kept separately and each book should have a bookplate indicating that he was the donor. A plate was immediately designed and engraved, and the ex-libris labels were printed and sent to Doctor Smith, who had them placed in each one of the books. In January of the present year the first consignment of these books for the library was received, and they were at once placed in a separate stack in the Smithsonian building and kept together. The number sent amounted to 461 bound volumes, 100 unbound volumes, some incomplete, and 293 pamphlets.

EXCHANGES.

Special efforts have been made to meet the conditions coexistent with the third year of war in the matter of preserving and promoting foreign exchange relations, and the generous response met with has been very gratifying. On the other hand, a number of important publications have been suspended owing to the death or absence of collaborators; and still others will be withheld pending termination of the war, while the uncertainties of transportation have resulted in the loss of a number of valuable publications from abroad. The policy of broadening exchange relations with South and Central America has been inaugurated.

ACCESSIONS.

Additions to the library, consisting mainly of gifts and exchanges, were received in 24,292 packages. Of these, 23,307 were received by mail and 985 through the International Exchange Service. Correspondence in connection therewith amounted to about 1,245 letters and 2,126 acknowledgments on the regular printed forms.

The cataloguing, not including publications for the Bureau of American Ethnology and the National Museum, reported elsewhere, covered 3,546 volumes and 47 charts. Of these, 698 were new titles added to the author catalogue and 59 new periodicals. In addition to 1,500 printed cards received from the Library of Congress, 1,855 new typewritten cards were prepared. There were 976 volumes recatalogued.

SMITHSONIAN MAIN LIBRARY.

Publications for the Smithsonian main library have been forwarded to the Smithsonian deposit in the Library of Congress as

received, after being duly entered on the records. During the fiscal year 2,880 of these were catalogued and accessioned, consisting of 1,730 volumes, 301 parts of volumes, 805 pamphlets, and 44 charts, thereby extending the accession numbers from 525,256 to 527,150. Several thousand publications remained unaccessioned at the close of the year, owing to a position of cataloguer being vacant for over nine months. The existing practice of transferring to the Library of Congress, without stamping or recording, public documents received in exchange for Smithsonian publications, mainly of a statistical character, has been continued, with the result that 2,349 were forwarded in this manner.

During the year the titles of 757 new publications were added to the catalogue. Want cards to the number of 385 for series in the Smithsonian division at the Library of Congress were considered, with the result that 154 volumes, 571 parts of volumes, and 51 title-pages were secured, thus completing 44 sets to date. There were received from the periodical division 105 cards, action on which resulted in securing 9 volumes, 70 parts of volumes, and 32 title-pages; and in response to 32 cards from the order division, 28 volumes and 12 parts were obtained.

The number of dissertations and technological publications received showed a marked decrease over previous years. They were contributed by the following:

Kejserliga Alexanders-Universitet i Finland.
Technische Hochschule, Breslau.
Kungliga Tekniska Högskolan, Stockholm.
University of Würzburg.
University of Breslau.
Königlich Sächsische Technische Hochschule, Dresden.

Office reference library.—The accessions for the office library, which includes the Astrophysical Observatory and the National Zoological Park, amounted to 1,025 publications, distributed as follows: Office library, 899 volumes and pamphlets; Astrophysical Observatory, 55 volumes, 18 parts of volumes, and 39 pamphlets; National Zoological Park, 11 volumes and 3 pamphlets.

Reading room.—The reading room has now about 311 foreign and domestic periodicals, which have been in constant use by the staff and members of the scientific bureaus of the Government. During the year 3,701 publications from the reading and reference rooms were in circulation, of which 3,367 were single numbers of periodicals and 334 were bound volumes.

The aeronautical library.—The aeronautical library is probably one of the most complete series on the subject in the United States, and the policy has been to maintain it as such.

Before Doctor Langley came to the Smithsonian Institution as Assistant Secretary he had made a collection of what had been published relating to aeronautics. Later, when he became Secretary and published his epoch-making works "Experiments in Aerodynamics" and "Internal Work of the Wind," the number of publications was gradually growing, so that when his successful experiments were made with the heavier-than-air models the Institution had the most complete library of aeronautical literature in the United States. With this collection of books as a basis, a bibliography was prepared by me to cover all existing literature up to 1909. Since that time the securing of publications has continued, and every possible effort has been made to have it complete. Dr. Alexander Graham Bell, a Regent of the Institution, has also shown an interest in this collection by contributing his entire working library of books and newspaper clippings relating to aeronautics, arranged and mounted, which is a valuable addition in supplementing the series already in the Institution.

There are now on hand 1,600 volumes and 83 titles of periodicals. With the close of the year a second part of the bibliography of aeronautics is in preparation by me for the National Advisory Committee for Aeronautics, at the suggestion of the Secretary, which will complete the references from 1909 to the end of 1916.

Art room.—No additions have been made to the collection of publications relating to art in the art room, in view of the fact that all of those relating to the fine arts have been placed in the sectional library of administration for use in connection with the National Gallery of Art, and those relating to the reproductive processes for engraving have been placed in the sectional library of the division of graphic arts in the Museum.

Employees' library.—The condition of the employees' library has remained practically the same as last year, with no additions. If money were available it could be used to great advantage in adding some of the latest literature in fiction and other classes. The library has been in constant use, and 304 volumes were circulated during the year.

John Watts de Peyster collection.—This collection of Napoleona is probably the most unique collection of publications relating to Napoleon in the United States, and was brought together by Gen. John Watts de Peyster to include works relating to Napoleon as a general. It covers the period from the end of the Napoleonic wars to the present great struggle. There are many calls for these publications, and some means must be found to make them available. So far it has not been possible to do this with the present staff, and a cataloguer with a knowledge of French history should be employed for the special purpose of cataloguing this collection. Every effort is

being made now to make the books available, but without an adequate catalogue they can not be used to the fullest extent.

NATIONAL MUSEUM LIBRARY.

The value of the library of the National Museum is largely due to the systematic collecting of works relating to the subjects covered by the collections in the Museum and at the same time supplementing as far as possible series in other libraries of Washington. The books are consulted by persons carrying on research work in almost every branch of the Government service, including those who are doing scientific work along similar lines. The publications for the library come to the Museum by gift, by exchange of publications, and by purchase. Many important gifts have been received from specialists, and those received during the year are given in detail. The exchanges, as is the case with the Smithsonian library, have met with many difficulties raised by war conditions in the matter of securing foreign publications, which have been but partially overcome. The situation in this respect has, on the whole, shown no appreciable amelioration over the preceding year. Special effort, however, has been directed toward maintaining the foreign exchanges at the maximum compatible with existing conditions. In connection with this work 271 letters were written in securing a number of new titles and in filling "wants" in many of the incomplete sets on hand. The appropriation for the purchase of books is very small and has been the same for a number of years, and it is only by judicious spending that the urgent needs of the Museum can be secured.

The library was fortunate enough to secure by purchase the following three rare books, the editions of which are not represented in the United States:

Boddaert, P.: Elenchus animalium, I. Roterodami, 1784.
Forster, J. R.: Afrikanischen Vögel, Halle, 1798.
Vroeg, A.: Catalogus . . . Vogelen, etc., s'Gravenhage, 1764, with separately paged "adumbratiunculae."

Mearns collection.—One collaborator who had taken a special interest in the library was Dr. Edgar A. Mearns, the announcement of whose death was received with deep regret last fall. Doctor Mearns contributed publications to the library each year as well as a collection of Korans, and after his demise his widow carried out his expressed wish in presenting the remainder of his scientific library to the Museum. This collection is especially rich in works on mammals, birds, and plants.

Dall collection.—The continued interest of Dr. William Healey Dall in the books relating to mollusks, which form the sectional library of the division of mollusks, has resulted in the further addition of 307 titles during the past year.

Other members of the scientific staff who have contributed to the collection in the library are: Dr. C. D. Walcott, Dr. O. P. Hay, Dr. C. W. Richmond, Mr. W. R. Maxon, Mr. W H Holmes, Dr J. C. Crawford.

Accessions.—There are now in the Museum library 132,203 publications, consisting of 49,285 volumes, 82.794 pamphlets and unbound papers, and 124 manuscripts. Of these, 1,372 volumes, including 949 completed volumes of periodicals, 3.550 pamphlets, and 65 parts of volumes, were accessioned during the past year.

Cataloguing.—As in the past, new material has been promptly entered and placed on the shelves or assigned to the sectional libraries. The cataloguing covered 623 books, 949 completed volumes of periodicals, and 373 pamphlets; in addition, 10,142 periodicals were entered. There were also 4,522 section cards made out covering publications assigned to sectional libraries.

Loans.—The loans from the general library during the year covered by this report totaled 12,869 publications, in which are included 3,085 books borrowed from the Library of Congress, including the Smithsonian deposit, and 490 books borrowed from other libraries. In addition, 5,580 books were consulted in the reading room of the library.

Binding.—The serious situation with regard to publications remaining unbound is being gradually relieved, but much remains to be done. During the past year 1,377 such publications were prepared for binding and sent to the Government binder. Of these 685 were returned within the year.

Technological series.—Additions to the technological library were composed of 374 volumes, 3,826 parts of volumes, 802 pamphlets, and 5 maps. There were filed 352 cards for books catalogued. A file of approximately 2,500 printed cards covering Smithsonian publications was received and incorporated in the catalogue. In the scientific depository catalogue 1,507 author cards were filed, and to 4,515 additional cards subject headings were added, increasing the catalogue by 6,022 cards.

Books and periodicals loaned during the year numbered 133 volumes and 297 parts of volumes and pamphlets, making a total circulation of 430 publications. About 620 volumes were consulted in the reading room of the library.

Several sets have been rearranged and more logically classified. In addition, a set of duplicates has been gone over, sorted, and arranged by class number. Of the duplicates received [illegible] were volumes and 1,328 parts of volumes and pamphlets.

Sectional libraries.—The series of publications in the sectional libraries were dormant until a few years ago, and no effort was made to add to the collection of books in these libraries, the whole

matter being held in abeyance until the work on the collections had been resumed. Books on the various subjects covered have, therefore, been sought and the number augmented. During the interval, however, the future need of publications for working up the collections was never lost sight of and there was a number of the serials bound and ready for use. Toward the end of the year two cataloguers were employed in the division of mineral technology to put the books on hand in the very best of order and for the making of a special author and subject catalogue, so that with the close of the year the work has been completed and this sectional library is in excellent condition. It is hoped that during the present year it will be possible to do the same thing for the division of textiles. This will, however, not be possible with the present force, which is too small.

With the death of Mr. Thomas W. Smillie, who was for many years custodian of the section of photography in the division of graphic arts, it was necessary that all books in the section should be checked up. A special cataloguer was employed for the purpose and the books and pamphlets were put in order and catalogued, periodical series arranged on the shelves and lacking numbers indicated in order that sets could be completed. The work was finished by June 30.

The following is a complete list of the sectional libraries:

Administration.
Administrative assistant's office.
Anthropology.
Biology.
Birds.
Botany.
Comparative anatomy.
Editor's office.
Ethnology.
Fishes.
Forestry.
Geology.
Graphic arts.
History.
Insects.
Invertebrate paleontology.
Mammals.
Marine invertebrates.
Materia medica.
Organic industries.
Mechanical technology.
Mesozoic fossils.
Mineral technology.
Minerals.
Mollusks.
Oriental archeology.
Paleobotany.
Parasites.
Photography.
Physical anthropology.
Prehistoric archeology.
Property clerk.
Reptiles and batrachians.
Superintendent's office.
Taxidermy.
Textiles.
Vertebrate paleontology.

BUREAU OF AMERICAN ETHNOLOGY LIBRARY.

This library is administered under the direct care of the ethnologist in charge, and a report on its operations will be found in the report of that bureau.

ASTROPHYSICAL OBSERVATORY LIBRARY.

The collection of reference works relating to astrophysics has been in constant use. During the year 55 volumes, 18 parts of volumes, and 39 pamphlets were added to this library.

NATIONAL ZOOLOGICAL PARK LIBRARY.

This collection contains publications relating to the work of the park, and while not large is a strictly working library. During the past year 11 volumes and 3 pamphlets were added to the series.

SUMMARY OF ACCESSIONS.

The accessions during the year, with the exception of the library of the Bureau of American Ethnology, may be summarized as follows:

To the Smithsonian deposit in the Library of Congress, including parts to complete sets	2,886
To the Smithsonian office, Astrophysical Observatory, and National Zoological Park	1,025
To the United States National Museum	5,193
Total	9,104

Respectfully submitted.

Paul Brockett,
Assistant Librarian.

Dr. Charles D. Walcott,
Secretary of the Smithsonian Institution.

APPENDIX 7.

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

SIR:—I have the honor to submit the following report on the operations of the United States Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1917:

This international enterprise was, at the beginning of the present war, being carried on through the cooperation of the 34 following-named countries: Argentine Republic, Austria, Belgium, Canada, Chili, Cuba, Denmark, Egypt, Finland, France, Germany, Greece, Holland, Hungary, India and Ceylon, Italy, Japan, Mexico, New South Wales, New Zealand, Norway, Poland, Portugal, Queensland, Russia, South Africa, South Australia, Spain, Straits Settlements, Sweden, Switzerland, United States of America, Victoria and Tasmania, and Western Australia. Each of these countries supported a regional bureau whose duty it was to furnish to the central bureau in London classified index citations to all the scientific literature published within their several regions.

As the greater part of these countries are now actually engaged in hostilities it is natural that scientific research and publication would be much affected, and that such an international cooperative enterprise as the International Catalogue would find itself in many difficulties. Not only have the number of scientific papers being published greatly decreased but the difficulty of preparing and publishing a regular index has increased owing to the impossibility of obtaining necessary scientific and clerical assistance to aid in the preparation and publication of the Catalogue. The London central bureau was, however, able to publish four volumes of the Catalogue during the fiscal year; these volumes were the twelfth annual issue of geology and the thirteenth annual issue of chemistry, anatomy, and botany. All of the eleventh annual issue has now been published, together with 15 volumes of the twelfth annual issue, 13 volumes of the thirteenth annual issue, and 1 volume of the fourteenth annual issue, making a total of 216 regular volumes published since the beginning of the enterprise in 1901. In addition to these regular volumes several special volumes of schedules, lists of journals, etc., have been published.

Almost 3,000,000 references to current scientific publications are contained in these 216 volumes, about 12 per cent of which have been supplied by this bureau.

Owing to the dangers and difficulties of transportation much of the material prepared by this bureau for incorporation in the Catalogue during the present year has been held until such time as it can be safely forwarded to London.

It is not to be expected that the publication of the Catalogue can be regularly carried on until after the return of peace, but it appears that the organization is holding together better than might be expected under existing conditions and that when peace is declared it will only be necessary to resume, rather than reorganize, the work.

When it is possible for all the regional bureaus to fully resume the preparation of the Catalogue it is to be hoped that every effort will then be made to carry out one of the most important resolutions adopted at the last convention of the International Catalogue, held in London in 1910. This resolution was:

(1) To take all possible steps to prevent reduplication by the publication of several annual and similar Catalogues and indexes on the same subject, by making arrangements such as those now in force with the Zoological Society of London.

(2) To obtain further assistance and cooperation in the preparation of the material of the Catalogue from the principal scientific societies and academies and the organizations which collect material for indexing scientific literature.

Scientific bibliographic work is seldom if ever self-supporting, and after the war it will undoubtedly be more than ever necessary to exercise every possible economy in the preparation and publication of scientific indexes and yearbooks, so that the editors and publishers of all such publications will find it greatly to their advantage to cooperate with the International Catalogue to the fullest possible extent and thus prevent the reduplication referred to in the resolution quoted above. This will benefit not only the International Catalogue and the publishers of the other bibliographies, but will greatly lessen the labors of librarians and scientific investigators who have occasion to use such works of reference.

More than ever before the line of demarcation between the researches of pure science and the practical application of such researches is being eliminated, and laboratory experiments of to-day may to-morrow be in actual use in ways vitally affecting the welfare of man. It is becoming more than ever difficult to define what is pure science and what is applied science and the heretofore arbitrary, though at the time necessary, limitation of the scope of the International Catalogue to include papers on pure science only should now be so broadened as to include at least some of the applied

sciences, which have in the last few years advanced with such unprecedented strides. The inclusion of papers dealing with the application of scientific discoveries would undoubtedly greatly increase the size and cost of the Catalogue, but on the other hand its value and use would be so increased that the demand and consequent sales of the Catalogue would more than offset any additional cost.

Very respectfully, yours,

LEONARD C. GUNNELL,
Assistant in Charge.

Mr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

Appendix 8.

REPORT ON THE PUBLICATIONS.

Sir: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1917:

The Institution proper published during the year 1 memoir in the series of Contributions to Knowledge, 19 papers in the series of Miscellaneous Collections, and 6 special publications. The Bureau of American Ethnology published 1 annual report, 2 bulletins, and a list of publications of the bureau. The United States National Museum issued 1 volume of the Proceedings, 73 papers forming parts of this and other volumes, and 6 Bulletins.

The total number of copies of publications distributed by the Institution and its branches was 158,797, which includes 2,673 volumes and separates of the Smithsonian Contributions to Knowledge, 53,615 volumes and separate pamphlets of Smithsonian Miscellaneous Collections, 21,865 volumes and separate pamphlets of Smithsonian Annual Reports, 64,305 volumes and separates of National Museum publications, 11,964 publications of the Bureau of American Ethnology, 4,182 special publications, 23 volumes of the Annals of the Astrophysical Observatory, 29 reports of the Harriman Alaska Expedition, and 53 reports of the American Historical Association.

SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

QUARTO.

VOLUME 35.

No. 3. A contribution to the comparative histology of the femur. By J. S. Foote. February [illegible] 1917. ix+242 pp., 35 pls. (Publ. 2382.)

Title-page and table of contents. April 4, 1917. (Publ. 1740.)

SMITHSONIAN MISCELLANEOUS COLLECTIONS.

OCTAVO.

Of the Miscellaneous Collections, volume 63, 1 paper was published; of volume 64, 1 paper; of volume 66, 11 papers; of volume 67, 2 papers; of volume 68, 4 papers; in all, 19 papers, as follows:

VOLUME 63.

No. 6. Smithsonian Physical Tables. Second reprint of sixth revised edition. By F. E. Fowle. January 12, 1917. xxxvi+355 pp. (Publ. 2269.)

VOLUME 64.

No. 5. Cambrian Geology and Paleontology. III, No. 5. Cambrian trilobites. By Charles D. Walcott. September 29, 1916. Pp. 303–456, pls. 45–67. (Publ. 2420.)

VOLUME 66.

No. 6. Phonetic transcription of Indian languages. Report of Committee of American Anthropological Association. 15 pp. (Publ. 2415.)

No. 9. Maxonia, a new genus of tropical American ferns. By Carl Christensen. September 30. 1916. 4 pp. (Publ. 2424.)

No. 10. Three new murine rodents from Africa. By N. Hollister. October 26, 1916. 3 pp. (Publ. 2426.)

No. 11. On the use of the pyranometer. By C. G. Abbot and L. B. Aldrich. November 6, 1916. 9 pp. (Publ. 2427.)

No. 12. Bones of mammals from Indian sites in Cuba and Santo Domingo. By Gerrit S. Miller, jr. December 7, 1916. 10 pp., 1 pl. (Publ. 2429.)

No. 13. The teeth of a monkey found in Cuba. By Gerrit S. Miller, jr. December 8. 1916. 3 pp., 1 pl. (Publ. 2430.)

No. 14. Preliminary survey of the remains of the Chippewa settlements on La Pointe Island, Wisconsin. By Philip Ainsworth Means. January 4, 1917. 15 pp., 2 maps. (Publ. 2431.)

No. 15. Three remarkable new species of birds from Santo Domingo. By J. H. Riley. December 1, 1916. 2 pp. (Publ. 2435.)

No. 16. The determination of meteor orbits in the solar system. G. von Niessl. April 23, 1917. 35 pp. (Publ. 2436.)

No. 17. Explorations and field work of the Smithsonian Institution in 1916. April 28, 1917. 134 pp. (Illustrated.) (Publ. 2438.)

No. 18. On the occurrence of Benthodesmus atlanticus Goode and Bean on the coast of British Columbia. By C. H. Gilbert. February 21, 1917. 2 pp. (Publ. 2439.)

VOLUME 67.

No. 1. Cambrian Geology and Paleontology. IV, No. 1. Nomenclature of some Cambrian Cordilleran formations. By Charles D. Walcott. May 9, 1917. pp. 1–8. (Publ. 2444.)

No. 2. Cambrian Geology and Paleontology. IV, No. 2. The Albertella fauna in British Columbia and Montana. By Charles D. Walcott. May 9, 1917. pp. 9–59, pls. 1–7. (Publ. 2445.)

VOLUME 68.

No. 1. Archeological investigations in New Mexico, Colorado, and Utah. By J. Walter Fewkes. May 16, 1917. 38 pp., 14 pls. (Publ. 2442.)

No. 2. Recognition among insects. By N. E. McIndoo. April 30, 1917. 78 pp. (Publ. 2443.)

No. 3. Effect of short period variations of solar radiation on the earth's atmosphere. By H. Helm Clayton. May 21, 1917. 18 pp., 8 charts. (Publ. 2440.)

No. 4. Preliminary diagnosis of new mammals obtained by the Yale-National Geographic Society Peruvian Expedition. By Oldfield Thomas. April 10, 1917. 3 pp. (Publ. 2447.)

SMITHSONIAN ANNUAL REPORTS.

Owing to the congestion of work at the Government Printing Office on account of the war, the Smithsonian Report for 1916, which was ready for printing in April, was not yet off the press at the close of the fiscal year.

SPECIAL PUBLICATIONS.

The following special publications were issued during the year:

Publications of the Smithsonian Institution issued between January 1 and June 30, 1916. 3 pp. (Publ. 2422.)

Publications of the Smithsonian Institution issued between January 1 and September 30, 1916. 3 pp. (Publ. 2425.)

Publications of the Smithsonian Institution issued between January 1 and December 31, 1916. 3 pp. (Publ. 2437.)

Publications of the Smithsonian Institution issued between January 1 and March 31, 1917. 1 p. (Publ. 2449.)

Classified list of Smithsonian publications available for distribution December 15, 1916. vi+32 pp. (Publ. 2434.)

The Smithsonian Institution (descriptive folder). 17 pp. (Publ. AQ.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM.

The publications of the National Museum are: (*a*) The annual report to Congress; (*b*) the Proceedings of the United States National Museum; and (*c*) the Bulletin of the United States National Museum, which includes the Contributions from the United States National Herbarium. The editorship of these publications is vested in Dr Marcus Benjamin.

During the year the Museum published 1 volume of the Proceedings and 78 separate papers forming parts of this and other volumes, and 6 Bulletins.

The issues of the Proceedings were as follows: Volume 50; volume 51, papers 2130–2172; volume 52, papers 2173–2193; volume 53, papers 2194–2200, 2206, and 2210–2212.

The Bulletins were as follows:

Bulletin 71. A monograph of the foraminifera of the North Pacific Ocean, Part VI. Miliolidae, by Joseph A. Cushman.

Bulletin 93. The sessile barnacles (Cirripedia) contained in the collections of the U. S. National Museum; including a monograph of the American species, by Henry A. Pilsbry.

Bulletin 96. A synopsis of American early Tertiary Cheilostome Bryozoa, by Ferdinand Canu and Ray S. Bassler.

Bulletin 98. The birds of the Anamba Islands, by Harry C. Oberholser.

Volume 16. Contributions from the U. S. National Herbarium, entitled "Systematic investigations in Phanerogams; ferns, and mosses," by various authors.

Volume 17. Contributions from the U. S. National Herbarium entitled "Systematic investigations in lichens and ferns, grasses, and other Phanerogams," by various authors.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

The publications of the bureau are discussed in Appendix 2 of the Secretary's report. The editorial work of the bureau has continued in charge of Mr. J. G. Gurley, editor.

During the year, 1 annual report, 2 bulletins, and a list of publications were issued, as follows:

Thirty-first Annual Report of the Bureau of American Ethnology (containing an accompanying paper "Tsimshian Mythology" (Boas)).

Bulletin 40, part 2 (edited by Boas), "Coos, an illustrative sketch," by Leo J. Frachtenberg.

Bulletin 55, Ethnobotany of the Tewa Indians, by Robbins, Harrington, and Freire-Marreco.

List of publications of the Bureau of American Ethnology.

At the close of the fiscal year there were in press or in preparation 4 annual reports and 7 bulletins.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION.

The annual reports of the American Historical Association are transmitted by the association to the Secretary of the Smithsonian Institution and are communicated to Congress under the provisions of the act of incorporation of the association.

Volume 1 of the annual report for 1914 was issued during the year, and volume 2 of this report and the report for 1915 were in press at the close of the year.

REPORT OF THE NATIONAL SOCIETY OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The manuscript of the Nineteenth Annual Report of the National Society of the Daughters of the American Revolution for the year ending October 11, 1916, was communicated to Congress on February 5, 1917.

THE SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION.

The editor has continued to serve as secretary of the Smithsonian advisory committee on printing and publication. This committee passes on all manuscripts offered for publication by the Institution or its branches, and considers forms of routine, blanks, and various other matters pertaining to printing and publication. Sixteen meetings were held during the year and 101 manuscripts were acted upon.

Respectfully submitted.

A. Howard Clark, *Editor.*

Dr. Charles D. Walcott,

Secretary of the Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1917.

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution, and a statement of the appropriations by Congress for the National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, and the International Catalogue of Scientific Literature for the year ending June 30, 1917, together with balances of previous appropriations:

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1917.

Section 5591, Revised Statutes, reads as follows:

The Secretary of the Treasury is authorized and directed to receive into the Treasury, on the same terms as the original bequest of James Smithson, such sums as the Regents may, from time to time, see fit to deposit, not exceeding, with the original bequest, the sum of one million dollars.

On July 18, 1916, and on January 11, 1917, two amounts of $2,000 each, consisting of savings from income, were deposited in the Treasury of the United States and completed the total deposit of $1,000,000 allowed by law. The amount of each fund so deposited and drawing interest at the rate of 6 per cent per annum is given below:

Smithson fund	$727,640.00
Habel fund	500.00
Hamilton fund	2,500.00
Hodgkins fund	216,000.00
Rhees fund	590.00
Avery fund	14,000.00
Addison T. Reid fund	11,000.00
Lucy T. and George W. Poore fund	26,670.00
George K. Sanford fund	1,100.00
Total fund in United States Treasury	1,000,000.00

OTHER RESOURCES.

Registered and guaranteed 4 per cent bonds of the West Shore Railroad Co., part of legacy of Thomas G. Hodgkins (par value)	$42,000.00
Coupon 5 per cent bonds of the Brooklyn Rapid Transit Co., due July 1, 1918 (cost)	5,040.63
Coupon 6 per cent bonds of the Argentine Nation, due Dec. 15, 1917 (cost)	5,093.75
	1,052,134.38

Also three small pieces of real estate, two of which are improved, located in the District of Columbia and bequeathed by the late Robert Stanton Avery, of Washington, District of Columbia.

Statement of receipts and disbursements from July 1, 1916, to June 30, 1917.

RECEIPTS.

Cash on deposit and in safe July 1, 1916		$44,711.02
Interest on fund deposited in United States Treasury due July 1, 1916, and Jan. 1, 1917	$59,810.50	
Interest on West Shore Railroad bonds due July 1, 1916, and Jan. 1, 1917	1,650.00	
Repayments, rentals, publications, etc.	10,628.03	
Contributions for specific purposes	16,030.00	
		89,440.62
		134,151.64

DISBURSEMENTS.

Buildings, care and repairs		$6,802.23
Furniture and fixtures		1,594.45
General expenses:		
Salaries	$19,257.45	
Meetings	69.00	
Stationery	1,244.77	
Postage, telegraph, and telephone	559.33	
Freight	59.64	
Incidentals, fuel, and lights	1,217.51	
Garage	2,487.44	
		24,801.14
Library		2,440.64
Publications and their distribution:		
Miscellaneous Collections	5,190.95	
Contributions to Knowledge	551.00	
Reports	188.57	
Special publications	420.09	
Publication supplies	132.47	
Salaries	7,589.33	
		13,081.25

Explorations, researches, and collections		$5,004.10
Hodgkins specific fund, researches, and publications		6,408.24
International Exchanges		5,857.02
Gallery of Art		100.05
Langley Aerodynamical Laboratory		2,092.60
Deposit to credit of permanent fund		4,000.00
Advances for field expenses, etc		25,610.17
Bills receivable, certificates of deposit		25,000.00
		124,127.08
Deposited with the Treasurer of the United States and in bank	$9,032.56	
Cash on hand	200.00	
		9,232.56
		133,359.64

The itemized report of the auditor confirms the foregoing statement of the balances, receipts, and expenditures, and is approved. A summary of the report follows:

CAPITAL AUDIT CO., METROPOLITAN BANK BUILDING,
Washington, D. C., August 24, 1917.

Executive Committee, Board of Regents, Smithsonian Institution.

SIR: We have examined the accounts and vouchers of the Smithsonian Institution for the fiscal year ended June 30, 1917, and certify the following to be a correct statement:

Total disbursements	$124,127.08
Total receipts	68,648.62
Excess of disbursements over receipts	55,478.46
Amount from July 1, 1916	64,711.02
Balance on hand June 30, 1917	9,232.56
Balance as shown by Treasury statement as of June 30, 1917	12,057.11
Less outstanding cheques	4,110.07
Balance	7,947.04
Balance American National Bank	1,085.52
Cash on hand	200.00
Balance June 30, 1917	9,232.56

The vouchers representing payments from the Smithsonian income during the year, each of which bears the approval of the Secretary, or in his absence, of the Acting Secretary, and a certificate that the materials and services charged were applied to the purposes of the Institution, have been examined in connection with the books of the Institution and agree with them.

CAPITAL AUDIT CO.,
By WILLIAM L. YAEGER, *President.*

All payments are made by check signed by the Secretary on the Treasurer of the United States and all revenues are deposited to the credit of the same account, except in some instances small deposits are now made in bank for convenience of collection.

Your committee has approved of the deposit on time in strong Washington banks and trust companies of a part of its cash resources not immediately required, and has been able to obtain interest thereon at the rate of 3 per cent per annum. It is believed that approximately $1,000 can be added each year to the revenues of the Institution by this procedure.

Your committee also presents the following summary of appropriations for the fiscal year 1917, intrusted by Congress to the care of the Smithsonian Institution, balances of previous appropriations at the beginning of the fiscal year, and amounts unexpended on June 30, 1917.

	Available after July 1, 1916.	Balance June 30, 1917.
International Exchanges, 1915	90.20	[1] 90.20
International Exchanges, 1916	1,244.17	
International Exchanges, 1917	32,000.00	4,957.78
American Ethnology, 1915	1,119.04	[1] 812.84
American Ethnology, 1916	2,597.79	334.17
American Ethnology, 1917	42,000.00	1,522.29
International Catalogue, 1915	194.39	
International Catalogue, 1916	540.83	182.58
International Catalogue, 1917	7,500.00	466.05
Astrophysical Observatory, 1915	46.55	[1] 46.55
Astrophysical Observatory, 1916	1,723.21	88.06
Astrophysical Observatory, 1917	13,000.00	1,081.22
Bookstacks for Government bureau libraries, 1916	1.09	[1] 1.09
Bookstacks for Government bureau libraries, 1915-16	64.16	62.12
Tower telescope on Mount Wilson, 1915	410.22	
Repairs to Smithsonian building, 1916	176.88	[1] 176.88
National Museum:		
Furniture and fixtures, 1915	13.34	[1] 13.34
Furniture and fixtures, 1916	1,041.95	11.36
Furniture and fixtures, 1917	25,000.00	2,346.75
Heating and lighting, 1915	109.83	[1] 109.83
Heating and lighting, 1916	5,532.06	302.67
Heating and lighting, 1917	48,000.00	8,474.09
Preservation of collections, 1915	1,274.34	[1] 1,274.70
Preservation of collections, 1916	7,996.91	1,777.90
Preservation of collections, 1917	300,000.00	6,871.80
Books, 1915	115.00	[1] 56.88
Books, 1916	1,167.49	233.81
Books, 1917	2,000.00	911.15
Postage, 1917	500.00	
Building repairs, 1915	1.33	[1] 1.33
Building repairs, 1916	2,398.68	2.62
Building repairs, 1917	10,000.00	2,120.30
National Zoological Park, 1915	.87	[1] .87
National Zoological Park, 1916	5,442.00	9.39
National Zoological Park, 1917	100,000.00	2,402.55

[1] Carried to credit of surplus fund.

Statement of estimated income from the Smithsonian fund and from other sources, accrued and prospective, to be available during the fiscal year ending June 30, 1918.

Balance June 30, 1917		$9,232.56
Bills receivable	$25,000.00	
Interest on fund deposited in United States Treasury due July 1, 1917, and Jan. 1, 1918	60,000.00	
Interest on West Shore Railroad bonds due July 1, 1917, and Jan. 1, 1918	1,680.00	
Exchange repayments, sale of publications, refund of advances, interest, etc.	11,624.46	
Deposits for specific purposes	12,000.00	
		110,304.46
Total available for year ending June 30, 1918		119,537.02

Respectfully submitted.

George Gray,
Alexander Graham Bell,
Ernest W. Roberts,
Executive Committee.

[illegible]

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDING JUNE 30, 1917.

ANNUAL MEETING, DECEMBER 14, 1916.

The Board of Regents met at the Institution at 10 o'clock a. m.

Present: The Hon. Edward D. White, Chief Justice of the United States, Chancellor, in the chair; the Hon. Thomas R. Marshall, Vice President of the United States; Senator Henry Cabot Lodge; Senator Henry F. Hollis; Representative Ernest W. Roberts; Representative James T. Lloyd; Dr. Alexander Graham Bell; Mr. Charles F. Choate, jr.; Mr. John B. Henderson; and the Secretary, Mr. Charles D. Walcott.

APPOINTMENT OF REGENTS.

The Secretary announced that on December 14, 1915, the Speaker of the House of Representatives had reappointed Mr. Ferris and Mr. Roberts, Members of the House, as Regents, and appointed Mr. James T. Lloyd, of Missouri, a Regent to succeed Mr. Maurice Connolly, whose term as Representative had expired.

The Secretary also announced that Dr. A. Graham Bell had been reappointed a Regent by joint resolution of Congress approved by the President on February 21, 1916.

EXECUTIVE COMMITTEE APPOINTMENT.

On motion, Doctor Bell was reelected a member of the executive committee.

RESIGNATION OF REGENT.

The Secretary read the following letter from Dr. Andrew D. White tendering his resignation as a Regent of the Institution:

[Andrew D. White, Cornell University.]

ITHACA, N. Y., *December 7, 1916.*

Prof. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution, Washington, D. C.

MY DEAR MR. SECRETARY: Permit me to present, most respectfully, through you to the Board of Regents of the Smithsonian Institution, my resignation

from membership in their honorable body. My reason for so doing is the fact that the infirmities of age have made it of late very difficult, if not impossible, for me to render the services which are justly expected from everyone honored by such membership.

May I ask you also, in so doing, to accept for yourself and to tender to the board, with assurances of my sincere respect, my most hearty thanks for their unvarying kindness and courtesy in all the relations between us.

I remain, dear and honored sir, most respectfully yours,

ANDREW D. WHITE.

Senator Lodge offered the following resolutions, which were unanimously adopted:

Whereas the Board of Regents of the Smithsonian Institution having learned that Dr. Andrew Dickson White has tendered his resignation as a Regent: Therefore be it

Resolved, That the board records its deep regret at the severance of official relations with their distinguished colleague, and their appreciation of his valued services to the Institution extending over a period of nearly 20 years.

Resolved, That the Regents desire to convey to Doctor White an expression of their sincere hope that the future may bring to him the full measure of happiness that comes from a long life devoted to his country and to the welfare of mankind.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

In the absence of Judge Gray, chairman of the executive committee, Doctor Bell offered the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1918, be appropriated for the service of the Institution, to be expended by the Secretary with the advice of the Executive Committee, with full discretion on the part of the Secretary as to items.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

The Secretary submitted the annual report of the executive committee, showing the financial condition of the Institution for the fiscal year ending June 30, 1916, stating that it had been supplied to the Regents in printed form. On motion, the report was adopted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

The permanent committee submitted the following statement:

Hodgkins fund.—No further allotments from this fund have been made on account of the Langley Aerodynamical Laboratory.

An allotment of $6,000 per annum for three years has been made to Dr. Charles G. Abbot, director of the Astrophysical Observatory of the Smithsonian Institution, for the maintenance of an astrophysical station in the Argentine Republic for the purpose of determining the transmission of the sun's rays through the atmosphere. The details of this proposed work have been given by the Secretary in his annual report.

As previously reported, the sum of $2,000 was allotted from the Hodgkins fund to Dr. F. G. Cottrell for the conduct of experiments in the electrical precipitation of fog. These experiments have been concluded and Doctor Cottrell has submitted a report.

Chamberlain bequests.—Your committee reported at the last meeting that Dr. Leander T. Chamberlain had made two bequests to the Institution, one of $25,000 and one of $10,000, each of which was to be known as "The Frances Lea Chamberlain fund." The bequest of $10,000, the income of which is to be used for promoting the scientific value and usefulness of the collection of mollusks now in the National Museum and known as "The Isaac Lea collection," has been received and invested in two short-term bonds of $5,000 par value each.

Fiscal advisers.—Your committee met at the Smithsonian Institution on December 28, 1915, and Secretary Walcott explained the necessity for action by the committee in the matter of the investment of the funds of the institution over and above the $1,000,000 in the United States Treasury authorized by law, and on his recommendations resolutions were adopted appointing the American Security & Trust Co., of Washington, District of Columbia, and the firm of Spencer Trask & Co., of New York City, as the fiscal advisers of the committee. Both of these concerns have accepted and will serve without charge.

Consolidated fund.—The Secretary spoke in relation to the advantages in forming a consolidated fund for the purpose of pooling all of the funds that might belong to the Institution, with the exception of the $1,000,000 in the United States Treasury, and after discussion the committee adopted resolutions approving the policy of such a consolidated fund.

Freer Art Gallery.—The Secretary reported the receipt of the $1,000,000 provided by Mr. Charles L. Freer for the construction and equipment of the building to contain his art collections presented to the Institution. This sum had been deposited in various banks and trust companies, as follows: $900,000 at 3 per cent and $100,000 at 4 per cent.

On motion the report of the permanent committee was accepted and approved.

ANNUAL REPORT OF THE SECRETARY.

In presenting his annual report of the operations of the Institution for the fiscal year ending June 30, 1916, which had been printed and sent to the Regents, the Secretary said:

The publications of the Institution and its branches issued since the last meeting of the Regents number 113, aggregating about 7,000 pages and 775 plates of illustrations. The Institution proper issued 62 volumes and pamph-

lets (2,226 pages and 274 plates), the National Museum 48 volumes and pamphlets (4,322 pages and 450 plates), and the Bureau of American Ethnology 3 publications (800 pages and 50 plates). The total number of copies of all these series of publications distributed during the year was about 201,500—an increase of more than 50,000 over the preceding year. The annual report of the American Historical Association and of the National Society of the Daughters of the American Revolution were also transmitted through the Institution to Congress, as required by law.

As usual these publications cover nearly every branch of natural and applied science. Among those of the Institution proper I may mention two papers on aeronautics, one on wind tunnel experiments at the Massachusetts Institute of Technology, the other on the dynamical stability of aeroplanes, both by Assistant Naval Constructor J. C. Hunsaker and associates; four papers from the Astrophysical Observatory of the Institution dealing with the instruments used and observations made by the observatory staff in the study of solar radiation; three papers by your Secretary describing his researches in Cambrian geology and paleontology; two reprints of the Smithsonian Physical Tables, made necessary by the demand for this useful work; a paper by Chester G. Gilbert, of the National Museum, on sources of nitrogen compounds in the United States, which attracted considerable attention; and the usual semipopular account of the exploration and field work of the Institution during the year, which was more extensive and more profusely illustrated than ever before.

Of special interest among the numerous Museum publications may be mentioned a complete descriptive catalogue, by Dr. G. P. Merrill, of the valuable and extensive meteorite collection in the National Museum.

The Smithsonian report again appeared earlier than ever before, the complete volume for 1915 being received from the printer in June, 1916. The change in the size of the edition from 7,000 to 10,000 copies has proved very advantageous.

National Museum (including National Gallery of Art).—In many departments of the Museum extensive and valuable collections have been acquired, though none of the additions calls for special mention in this connection.

It is, however, considered very important that attention be drawn to the inadequacy of the present appropriations for carrying on the technical and exhibition work of the Museum, and while this deficiency applies in varying degree to all branches of the Museum, it is now more especially felt in connection with the art-industrial collections. The richest as a whole and the most varied of their kind in the country, planned by the Board of Regents in 1846, though not organized until 1881, and now filling the older Museum building as well as the main and western halls of the Smithsonian building, these collections are at present administered by so small a technical staff that it is impossible to make creditable progress with their classification and public installation, though it is through the development of these branches that the Museum offers the greatest practical benefits to the public at large. The immediate increase in funds required to attain this purpose is relatively inconsiderable,

but until even this small sum is secured the usefulness of the Museum must be greatly impaired.

National Gallery of Art.—Prominent among the artists represented in the extensive gift by Mr. William T. Evans of contemporary American paintings is Henry W. Ranger, of whose work the gallery possesses four examples. Mr. Ranger died on November 7, and by the terms of his will the National Gallery of Art is made a perpetual optional participant in the income of his estate, the value of which has been estimated at $250,000. The paragraph relating to the gallery, with reference to which it may be said that Mr. Ranger survived his wife, is as follows:

* * * * * * *

(2) Upon the death of my said wife, Helen Eudora Ranger, if she be living at the time of my death, or, if my said wife be not living at the time of my death, then as soon after my decease as may be practicable, I direct that my entire residuary estate be paid over to the National Academy of Design, the principal to be kept invested and the income thereof to be spent by the council of said academy in purchasing paintings produced by American artists, at least two-thirds (2/3) of such income to be spent in the purchase of works by artists who are forty-five years of age and over, it remaining optional with the council to spend the remaining one-third (1/3), or any part thereof, in the purchase of works by younger artists. All pictures so purchased are to be given by the council to art institutions in America, or to any library or other institutions in America maintaining a gallery open to the public, all such gifts to be upon the express condition that the National Gallery at Washington, administered by the Smithsonian Institute shall have the option and right, without cost, to take, reclaim, and own any picture for their collection, provided they exercise such option and right at any time during the five-year period beginning ten years after the artist's death and ending fifteen years after his death, and, if such option and right is not exercised during such period, the picture shall remain and be the property of the institution to which it was first given. The words "America" and "American" as used above shall be construed as equivalent to "North America" and "North American" respectively.

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Briefly analyzed, the purport of this bequest is that the National Gallery is given the opportunity of selecting, after a lapse of a period following his death sufficiently long to establish an artist's standing, such of his paintings purchased from the Ranger fund as may be regarded as desirable, without being placed in the position of refusing any. In the long run the gallery should derive very great benefits from this generous remembrance.

Freer Gallery of Art.—The board will recall that at the annual meeting of December 9, 1915, it approved the recommendation of the special committee on a site for the Freer Gallery of Art that the building be erected on the corner of the Smithsonian grounds at Twelfth and B Streets SW. This site was subsequently approved by the Federal Commission of Fine Arts, and also by Mr. Freer, who

transferred to the Institution the $1,000,000 he had set aside for the construction of the building.

On September 23, 1916, work was formally inaugurated by Mr. Rathbun, as Acting Secretary, who after a brief address reciting the history of this great gift, turned over the first spadeful of earth on the site selected. At this time the work of excavation for the foundations is proceeding as rapidly as possible, and it is expected to complete the building in two years, as estimated.

At the time of the original offer, the collection consisted of about 2,300 paintings and other objects of art, but it has since been increased to 5,846 items, including American paintings and sculptures, the Whistler collection and oriental paintings, pottery, bronzes, and jades from China, Japan, and other Asiatic countries.

It is also gratifying to call attention to recent announcements from Mr. Freer, that important additions are still being procured for his collections in the Far East; that several distinguished experts are preparing descriptive catalogues of parts of the collections; and that two Japanese artists are at work mounting and making ready for exhibition in the building the remarkable series of Chinese paintings, constituting one of the most valuable features of this important donation.

National Portrait Gallery.—The secretary called attention to the desirability of adding to the National Portrait Gallery, and stated that one of the best paintings extant of Joseph Henry, the first Secretary of the Smithsonian Institution, was now in the rooms of the Sergeant at Arms of the Senate; and that a painting of Benjamin West, made by that great artist himself, was in the Senate library committee room. He thought these should be turned over to the Institution and suggested that a committee be appointed to take care of the matter.

After discussion, on motion, Senators Lodge and Stone were appointed a committee to consider the means by which these portraits might be transferred to the care of the Institution.

Bureau of American Ethnology.—The researches of the Bureau of American Ethnology have been successfully prosecuted since the beginning of the present fiscal year and a large body of manuscripts is in hand or in process of printing. Excavation of a large pueblo ruin in the Mesa Verde National Park of Colorado has been conducted with the cooperation of the Department of the Interior; field investigations have been continued among the remnant tribes of southern California, the Fox Indians of Iowa, the Quileute of Washington, the Iroquois of Ontario, and the Cherokee of North Carolina; and the preparation of memoirs on other specific tribes, as well as handbooks on general subjects of ethnology and anthropology, are in varying stages of completeness.

National Zoological Park.—The latest action in the proceedings for acquiring land between the park and Connecticut Avenue was the decision of the court on January 28, 1916, setting aside all remaining benefits assessed against neighboring property. The valuation of the land to be taken and the cost of the proceedings together made a total of $106,641.43, the sum required for the purchase of the land. The appropriation of $107,200 originally made having lapsed, and efforts to have the necessary appropriation made at the last session of Congress having failed, an item for the sum required has been submitted in the estimates for 1918, with a clause to make it a continuing appropriation.

Cooperating with the New York Zoological Park and the Philadelphia Zoological Garden, the park agreed early in the summer to share in the expense of sending an experienced man to South Africa for animals, the supply through the usual animal dealers having been almost entirely cut off. Advices just received from him indicate that he is having much success in securing animals, especially from the zoological gardens there, which also are anxious to arrange for exchange with similar institutions in this country. The relations established by this means with the zoological gardens and naturalists of South Africa are likely to be very valuable in the future.

On November 1, 1916, Mr. Ned Hollister, for several years assistant curator of mammals in the United States National Museum, was appointed superintendent of the National Zoological Park to succeed Dr. Frank Baker, resigned.

Astrophysical Observatory work on Mount Wilson, 1916.—Messrs. Abbot and Aldrich occupied the Smithsonian observing station on Mount Wilson, California, from June to October, 1916, inclusive, continuing the series of observations of the solar radiation in order to follow the variations of the sun.

Despite much unfavorable weather, very satisfactory results were obtained along several lines. From numerous experiments it is indicated that the solar radiation, as in 1915, was decidedly higher during 1916 than during the sun-spot minimum period which culminated in 1913.

The new vacuum bolometer and stellite mirrors were introduced in the spectroscope, and a long series of careful determinations was made to determine the transmission of the spectroscope in this form. This new vacuum bolometer is about 20 times as sensitive as its predecessor.

Many experiments were made with the new instrument, the pyranometer, on the light of the sky. A new method of determining the solar variation by aid of the pyranometer is being tried, which, if successful, may enable many observers, not able to undertake the ex-

pensive and complicated investigation with the spectrobolometer, to take a part in observing the variability of the sun.

The Langley Aerodynamical Laboratory.—At the annual meeting of the Board of Regents held December 9, 1915, the Secretary reported that authority for the appointment by the President of an Advisory Committee for Aeronautics had been granted March 3, 1915, and that the advisory committee has been appointed, and further that—

In view of the scope and organization of the National Advisory Committee for Aeronautics, it is not deemed probably that the Smithsonian Institution will find it necessary to establish an aerodynamical laboratory for experimental purposes.

In the act approved August 29, 1916, making appropriations for the naval service for the fiscal year 1917, there is appropriated for the Advisory Committee for Aeronautics $85,000 in addition to the sum of $5,000 previously provided. This appropriation is for the necessary expenses of the committee and for experimental work, investigations, and publications.

In the same act there is also appropriated $3,500,000 for aviation; and in the Army appropriation act, also approved August 29, 1916, there is made available for the same purpose the sum of $13,281,666.

Your Secretary, as chairman of the executive committee of the National Advisory Committee for Aeronautics, has given considerable time and thought to the development of aviation in connection with the needs of the Government. Many meetings of the committee have been held and visits made to the principal plants where there was a prospect of the development and manufacture of aircraft and motors.

The present prospect is exceedingly favorable for the manufacture in quantity of an efficient aircraft motor at plants in New Jersey, Boston, Detroit, and Buffalo.

It may be of interest to state that the biplane is the standard airplane at present, and there is an immediate prospect that high-powered biplanes and possibly triplanes will be largely used where great speed and climbing power are essential.

An allotment of $2,500 for the study of problems of the atmosphere in relation to aeronautics has been made in connection with the United States Weather Bureau to provide for the beginning of an investigation which will ultimately result in the mapping of the atmosphere over the United States and adjoining areas up to a height of 20,000 feet.

It is anticipated that the Advisory Committee for Aeronautics, in cooperation with the War and Navy Departments, will at an early date have facilities for directing experimentation and investigations at suitably equipped aviation grounds, or laboratories, as a plat of land

1,000 acres in extent near Hampton, Virginia, has been purchased for use in this connection. This first great aviation field will be known as Langley Field.

Research Corporation.—That the Research Corporation has continued its growth during the year is shown by the fact that whereas in my last report. I stated that its salary roll for the ensuing year would be in the neighborhood of $88,000, at the present time it is at the rate of $120,000 a year.

The development of the Cottrell precipitation process has gone on to such an extent that it is now being employed for the precipitation of the dust in the air supplied to factories and to many other places where it is essential in protecting the health and lives of employees to rid the air of dust.

Fog precipitation.—As stated at the last meeting, an allotment of $2,000 from the Hodgkins fund was made to Dr. F. G. Cottrell to further his studies and experiments in the electric precipitation of fog. He has rendered an account of expenditures under this allotment and submitted a full report of his work, which indicates that the dispersion of fog by electricity is well within the bounds of possibility. The question of printing this report is now being considered.

Harriman trust fund.—Work under this fund by Dr. C. Hart Merriam has been continued along the lines mentioned in previous reports. Field work in northern California in advancing studies previously under way in ethnology and in the geographic distribution of animals and plants was carried on during the latter part of the summer, mainly in the Clear Lake region and the mountains to the northward; but work on the big bears has occupied the greater part of the year.

A revision of the species of grizzly and big brown bears has been prepared for the press, but owing to the absence of adult specimens from certain localities, several problems still remain unsolved. The effort to secure the needed material has been pressed with renewed vigor. As a result it is gratifying to report that about 150 skulls, including adult males of species the males of which were previously unknown, have been added to the collection, chiefly from localities in Alaska, Yukon Territory, and British Columbia.

Alberta and British Columbia expedition. The Secretary continued his geological work along the Continental Divide of western Alberta and eastern British Columbia, with the object of determining the geological horizon of the subfauna of the Cambrian series of rocks and the determination of the age of a geological formation the position of which has been called in question by Canadian geologists. The two problems were worked out successfully and some collections of fossils were secured. Much larger results would have been obtained if it had not been for the unusual cold and the heavy snow-

falls in May and June, and for the very wet and cold weather during the summer months.

Borneo and Celebes expedition.—Mention has been made on several occasions of the generosity of Dr. W. L. Abbott, a collaborator of the National Museum, whose gifts of ethnological and zoological specimens to the museum have been both extensive and valuable. In 1912 Doctor Abbott contributed a sum of money to defray the expenses of an expedition to Borneo, and annually since then he has added materially to his contributions. Since the last meeting he has given $4,000 for the continuation of these explorations, which are being conducted by Mr. H. C. Raven. The last expedition, which started October 19, 1916, includes the Dutch East Indies, and particularly Celebes, from which one shipment has already been received, while a second is on the way. Doctor Abbott's contributions to these expeditions now totals around $17,000. Formal acknowledgment of these generous gifts has been made.

Doctor Abbott's Santo Domingo expedition.—Doctor Abbott has but recently returned from a collecting trip through the island of Santo Domingo, West Indies, and has given further evidence of his interest in the National Museum by presenting to it the results of his labors there, viz, 230 anthropological specimens, 70 birds, 60 mammals, 20 reptiles, 100 insects, and a collection of mollusks. Doctor Abbott is now preparing for a trip to Haiti.

North China expedition.—Mr. A. de C. Sowerby is still conducting biological exploration work in Manchuria and northeastern China. This expedition has been financed by a generous friend of the Institution who will not permit his name to be known. No detailed report of the work is possible, though it is progressing in a satisfactory manner.

The Collins-Garner Congo expedition.—An expedition to the French Congo and neighboring parts of Africa has been arranged for the purpose of collecting natural history specimens for the National Museum. The members of the expedition will be Mr. Alfred M. Collins, of Philadelphia; Mr. Robert L. Garner, Mr. C. W. Furlong, and Mr. Charles R. W. Aschemeier. Mr. Collins agrees to meet the expenses of the first three gentlemen named, while the Institution will take care of Mr. Aschemeier, who goes as its special representative. The expedition will leave New York in a few days and is expected to return in about one year.

Kitchen midden material.—Mr. George Heye, of New York, has presented the Institution with a collection of material from kitchen middens in the West Indies, which contains matter of great interest, including bones of new species of mammals, and additional material is expected.

Carnegie Corporation gift of $6,000 to International Catalogue of Scientific Literature.—The International Catalogue of Scientific Literature has been confronted with serious financial embarrassment in the issuing of its annual catalogue by the difficulty in collecting subscriptions owing to the war in Europe. The Royal Society of London has been kindly making up deficits until this year, when an appeal for aid was made to the United States. The interest of the Carnegie Corporation of New York was enlisted in the matter and that establishment very generously contributed the sum of $6,000, making possible the publication of the fourteenth annual issue of the catalogue.

Cinchona Botanical Station.—The British Association for the Advancement of Science, which has maintained the Botanical Laboratory at Cinchona, Jamaica, for many years, announced some time since that owing to financial difficulties the station would probably have to be closed.

This decision was considered by a committee representing 14 American institutions engaged in botanical research, and after discussing the statement of the Jamaica Government that the station would be leased at an annual rental of $250, secured the necessary amount. The committee then concluded that the matter of the lease of the station should be placed in the hands of a widely recognized American scientific establishment, and invited the Smithsonian Institution to act as agent in this connection. After consideration, it was decided in the interest of botanical science, to accept the invitation, and accordingly the Institution has received the subscriptions of the 14 botanical institutions referred to, totaling $280, and has taken steps to secure the lease. It is understood that all questions relating to the admission of investigators will be determined, during the continuance of the European war, by the Colonial Government.

ADJOURNMENT.

There being no further business to transact, the board adjourned, after which the Regents viewed a small exhibit of anthropological and technological material, illustrating some of the lines along which the Institution works.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1917.

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the Secretary, induced in part by the discontinuance of an annual summary of progress which for 30 years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1917.

PROJECTILES CONTAINING EXPLOSIVES.[1]

By Commandant A. R.

Translated from Revue générale des Sciences pures et appliquées, volume 27, pages 213–221, April 15, 1916, by Charles E. Munroe.

The idea of employing powerful explosives as interior charges for projectiles dates from the discovery of guncotton by Schönbein. On the appearance of this substance its explosive power and its insolubility in water immediately attracted the attention of the military services of the different countries to it. Up to then black powder only furnished the interior charges for shells and bombs.

In France the pyroxylin commission, presided over by the Duke de Montpensier, carried out numerous tests for the purpose of determining the practicability of this material, but repeated explosions, in the bore, of projectiles charged with guncotton caused the abandonment of the researches.

It was not until 1886, following the work of Turpin on the priming of picric acid, that the question of charging projectiles with high explosives was taken up again in France, and this led to definite results.

I. STATE OF THE QUESTION.

The number of explosive substances which have been prepared up to the present time is very considerable. However, in spite of the fact that many of them are employed in the industries, only a very small number of them can be utilized in charging projectiles. Such use is subject to imperative conditions which markedly limit the domain from which one may select an explosive for artillery.

A projectile exerts destructive effects on an obstacle either because of the kinetic energy which it possesses at the moment it strikes upon it or because of the energy liberated by the detonation of the interior charge of explosive which it carries. Finally, and if the obstacle is very resistant (such for example as plates of armor protecting the sides of ships), experience shows that the effect produced by the detonation of a charge exploded in contact is, in general, insufficient to cause the

[1] Reprinted by permission from the United States Naval Institute Proceedings, Vol. 43, No. 4, Whole No. 170, April, 1917.

rupture of the obstacle. This can not be accomplished except by the passage of the projectile itself through the armor plate. If it is sought to sweep away obstructions, the potential energy of the explosive charge carried by the projectile should be exercised at this point.

Inasmuch as a charge of explosive can not be projected to a great distance without its being inclosed in a highly resistant metallic envelope,[1] it follows that in practice they will always produce simultaneously the destructive effects of the characters considered above. Finally, one may consider the destruction of the personnel as a principal purpose in the employment of shells charged with an explosive. In this case one will seek to effect the rupture of the body of the shell into a large number of fragments animated with the highest possible initial velocity. In addition are the notable destructive effects produced by the shock of the explosion wave on the persons who are in close proximity to the center of explosion. It is evident that endeavors will be made to produce the one or the other of these effects.

1. CHARACTERISTICS OF EXPLOSIVES.

In order to secure the results of the study we propose it is expedient to study these in detail. We recall at the outset certain elementary views concerning the characteristics essential to explosives.

In this regard an explosive is theoretically defined by certain data the chief of which are its force, F, its potential, Q, and its rate of detonation. The force is represented by the following expression.

$$F=\frac{p_0 V_0 T}{273}$$

in which p_0 represents the atmospheric pressure (which is 1.033 kilos per sq. cm.), V the volume, in liters at 0° C. and 760 millimeters of pressure, of the gaseous products resulting from the explosion of 1 kilogram of the explosive, and T the absolute temperature of the explosion.

The potential, Q, represents the work corresponding to the indefinite expansion of the above mass of gas. If E designates the mechanical equivalent of heat and q_0 the heat liberated by the explosion then

$$Q=Eq_0.$$

The rate of detonation is that of the propagation of the phenomenon of explosion in traveling through a lead or tin tube filled with the explosive under consideration.

[1] It will be otherwise if it be attempted to project the explosive charge by means of rockets analogous to the old-fashioned war rocket.

Finally, the definition of an explosive from the point of view under consideration is completed by a knowledge of its aptitude for detonation which is evidenced by its sensitiveness to the blow of a hammer of given mass (20 to 30 kilos) falling from a determined height, or by its sensitiveness to detonation by a detonator containing a given weight of mercury fulminate.

The following table gives the values for the force and potential pertaining to commonly occurring explosives:

	F.	G.
		Ton meters.
(1) Gunpowder	2,920	270
(2) Mercury fulminate	3,000	173
(3) Ammonium nitrate	5,100	267
(4) Ammonium picrate	7,940	228
(5) Picric acid	9,010	230
(6) Cellulose endecanitrate (guncotton)	10,270	457
(7) Cellulose octonitrate (collodion cotton)	9,360	315
(8) Nitroglycerin	10,560	690

It may be said concerning the velocity of detonation that it attains its maximum value with crystalline bodies such as picric acid and nitromannite where it is of the order of 7,000 meters per second and falls to about 2,500 meters in liquid and plastic substances such as nitroglycerin and dynamite.

If we designate by Δ the value of the ratio ϖ/C where ϖ represents the weight of explosive contained in volume C and α the covolume[1] of the mass of gas produced in the explosion (that is to say, the volume limit occupied by this gas under an infinite pressure), Noble and Abel have shown that the pressure, P (in kilos per sq. cm.), developed under these conditions on the walls of a receptacle G was defined by the formula

$$P=\frac{f\Delta}{1-\alpha\Delta}=\frac{f}{\frac{1}{\Delta}-\alpha}.$$

When the density of loading Δ becomes equal or superior to $1/\alpha$, the denominator of P becomes zero, and the pressure is infinite. Resistant as the envelope containing the explosive may be, it is then ruptured and the débris projected.

The interior of a projectile being supposedly filled with the explosive constituting the charge if its density is greater than $1/\alpha$ the preceding conditions are evidently fulfilled.

[1] Sarrau has shown that the value of α is for all gases very nearly V/1000.

Noble and Abel's formula supposes implicity that the composition of the gaseous products, and as a consequence the covolume of the entire mass, remain invariable whatever the pressure is. As a fact it is not so in most cases, because of the operation of the principle of the displacement of the equilibrium. In virtue of this principle the increase of the pressure of the mass of gas causes, when the change is possible, the formation of more and more condensed compounds and, in consequence, the diminution of the covolume.

It follows that the limit value of $1/\Delta$ can be such that it will always remain less than α. Hence the pressure can not become infinite. This is the case for guncotton.

The increase in the proportion of the condensed products is, on the other hand, generally explained by the correlative augmentation of the quantity of heat disengaged, q_{v}, and of the temperature, T, of the explosion. The force will then increase with the density of the charge. This is that which takes place in the case of picric acid.

From the standpoint of variations in the phenomena of detonation it may be said generally that the ability of an explosive to effect the rupture of its envelope is above all determined by an elevated value for its force and for its rate of detonation. Its destructive effect is chiefly a function of the magnitude of its heat, q, or contra, of its potential.

2. EFFECTS OF THE DETONATION OF EXPLOSIVES.

This summary of the theoretical views being disposed of we take up the description of the effects of detonation. We will suppose at the outset that the explosive is subjected to detonation in free air or when contained in a feebly resistant envelope. On explosion the gaseous mass which is produced expands in the direction of least resistance; that is to say, from below upward. This projection of the gas is accompanied with a violent aspiration of the layers of air in the vicinity of the ground, which aspiration is indicated by a brusque depression of the barometer whose intensity diminishes rapidly as the distance from the explosion center increases. Under the influence of this depression the air confined in near-by inclosures tends to escape outward and projects in that direction weakly resistant sides such as doors, windows, roofs and the like. The effect appears much as if a charge had been exploded within the inclosure.

Under the action of this movement of masses of air animated with a high horizontal velocity the layers near the periphery of the gaseous mass produced by the explosion, and which are animated with a vertical movement, acquire at times a most complete vortex motion. At the same time that this gaseous flow, which is often in a vertical direction, is set up, the detonation engenders a shock wave whose ve-

locity of propagation is at first much greater than that of sound, but which rapidly diminishes until it becomes the same as sound. There is thus produced an interruption of continuity and we know that in this case the difference in pressure existing at the front of the wave and the medium in which the latter is propagated may attain to a very notable value.

Numerous researches have been made on this subject in France and elsewhere. The more recent have been carried out by the commission on explosives[1] which has recognized that the limiting radius, r, of dangerous effects by the wave could be represented by the formula

$$r = K\sqrt{C}$$

in which r represents a length expressed in meters, C the weight of the charge in kilograms, and K a constant dependent on the nature of the explosive and the degree of security sought. It follows from this that for different charges the distances at which corresponding mechanical effects are produced are proportional to the square roots of the weights of the charges.

The detonation of 100 kilograms of melinite, for example, gave rise to a shock wave at whose surface there existed a pressure greater than 10 kilograms per square centimeter for a distance of 7 meters about the center of explosion. At 10 meters the pressure was between 2 and 3 kilograms, and at 15 meters it had fallen to less than one-half kilogram. Regarding the velocity of propagation of this wave we find it to have been 900 meters per second in the vicinity of the center of explosion, 635 meters at 5 meters farther away, 360 meters at a distance of 50 meters, and then down to 250 meters per second, which is the velocity of sound.

It follows from the preceding that a person located at some meters from the explosive charge will first be struck by the pressure from the shock wave, which will be followed by a sharp and sudden depression and movement of the air at high velocity toward the center of the explosion.

A fortuitous circumstance, recorded by M. Arnoux, has enabled us quite recently to elucidate the order of magnitude of this depression and to explain by the same the probable mechanism in numerous cases of dead bearing no apparent wounds which have been observed on the battlefield.

Last January M. Arnoux received from a superior officer at the front a pocket aneroid barometer which had been put out of service by the explosion of a German shell at a distance of about three meters from the instrument. On examination its parts were found intact but it could not register because the two transmission levers con-

[1] Memorial des Poudres et Salpêtres, 1905–6. Étude des effets à distance des explosions. M. Lheure, rapporteur.

nected with the indicating needle no longer rested on the other lever but had passed below. It was immediately apparent that this condition could have been caused only by an abnormal dilation of the aneroid system due to a considerable barometric depression. Under these circumstances the instrument had registered a pressure much below the minimum pressure inscribed on its graduated arc.

After having put the two levers in place the instrument was placed under the bell of an air pump and exposed to the vacuum. It was found that the two levers changed positions when the pressure on the interior had fallen to 410 millimeters of mercury. It was concluded that the explosion of the shell produced in its vicinity a static depression of 760—410=350 millimeters of mercury.

From the aerodynamic formulas it appears that the immediate production of this depression will give birth to a wind having a velocity of 270 meters per second and which will produce a dynamic pressure of 10,200 kilograms per square meter on a plane surface normal to the direction of its propagation.

Such a rush of air would overturn and crush to earth persons exposed to it. Those escaping would nevertheless suffer from the brusque depression, reckoned above, which would follow. Owing to this the air and carbon dioxide dissolved in the blood will be immediately set free in small bubbles, and, if their diameters are larger than those of the small arteries, they will form gaseous plugs which will instantly arrest the circulation of the blood in these arteries and death will occur before the re-solution in the blood on the restoration of the pressure to normal.

The passage of the sound wave at the outset of its formation can also rupture the eardrum, but its duration is extremely brief as compared with that of the following depression.

In all of the foregoing there has been only the single question of the mechanical effects due to the passage of the explosive from the solid to the gaseous state. The occurrences of the war have thrown light on the pathological rôle which the gases produced or liberated in detonation have come to play. Without wishing to enter on the study of projectiles designed for asphyxiation of the enemy we may remark that most of the nitro explosives employed in charging shell disengage notable proportions of carbon monoxid. Although the toxic power of this gas is relatively great, it may be observed here that it is not freed except when the explosion occurs out of contact with the air. This will, for example, be the case where a projectile is buried and exploded in the earth or a shell is exploded in a habitation of small size. In all other cases the carbon monoxid is immediately burned by the oxygen of the air in such manner that in reality only carbon dioxid is observed. It is known that man can

continue to live in an atmosphere containing a very large proportion of this latter gas.

Let us now examine the nature of the phenomena produced by the rupture of the metallic envelop constituting the body of the shell.

Different cases are distinguished according as to whether the body consists of cast iron or of steel. In the first case the metal is, as it were, pulverized by the explosive. The metallic powder produced by the explosion is projected with a great velocity; but, as the mass of the pieces is extremely small, they rapidly lose their velocity; in fact they have no efficiency after a course of a few meters.

By reducing the ratio of the weight of the charge to that of the projectile one can, it is true, somewhat improve the fragmentation. They can not, however, obtain a satisfactory result except by reducing the weight of the charge to such an extent that the effects of the blast and the momentum of the fragments become in themselves insufficient.

In addition to secure the necessary conditions of safety the walls of the cast-iron shell must be thicker than those of the steel shell, from which it results that the former is inferior to the latter from all points of view.

The rupture of the steel envelop is effected from the beginning in a totally different manner from cast iron. If the body of the shell is thin, it is torn into strips of relatively light weight.

The destructive effect from the action of the gas on loose soil manifests itself in the production of a cavity having the form of an elongated ellipsoid whose longer axis will be perpendicular to the horizontal projection of the trajectory. The difference in length of the two axes diminishes, other things being equal, the greater the depth to which the projectile has penetrated the ground before its explosion.

When the walls of the projectile are thicker the fragmentation changes in character and they note the production in place of the preceding chamfer strips, of fragments of irregular form, the average weight of which increases with the ratio of the weight of the projectile to that of its charge. For a given projectile the size of the pieces furnished by any part of it varies with the thickness of the walls at that point. The velocity of these pieces naturally varies inversely as their weight. This may be measured with the wire screens and the chronographs. The results obtained will be but average indications and often will be very inexact on account of the fact that the wires of the screen targets are sometimes broken by the shock wave before they can be cut by the fragments. Accepting this necessary condition it has been observed that the velocity of the fragments reaches and may surpass 1,200 meters per second when using a shell with thin walls.

The fragments of the ogival and base will be thrown with less velocity but nevertheless they will have a velocity greater than the residual velocity of the projectile.

II. ARRANGEMENTS OF THE EXPLOSIVE PROJECTILE.

The arrangement and proportioning of the parts of the explosive-containing projectile determine the functions it is to play. It may be required for the demolition and dispersion of weak defenses situated close at hand, and then thin-walled projectiles carrying large charges of explosives would be made use of, and as their resistance to the effects in firing is not great they would be discharged under low pressures.

In order to augment their range and penetration they would be fired at high angles near to or greater than 45°. It is advantageous to use for this short caliber pieces such as obuses or mortars.

If it is desired to produce destructive effects at great distances, the weight of the projectile and consequently the caliber will be increased. In case of unusually great distances, such as 20 kilometers or more, quite long cannon and high initial velocities must be employed. These guns are fired under high pressures and it is necessary to reinforce the walls of the projectiles to an equal caliber and reduce the interior explosive charge.

The considerations of a general nature relative to shell having been treated of, it remains to discuss those relative to the choosing of the explosive and the fixing of the charge.

1. CONDITIONS OF LOADING.

Industrial explosives are generally used in cartridges or sticks which are placed in bore holes in the interior of the material that is to be blown up. They are not, therefore, exposed to any violence.

The explosive charge of a shell must, on the contrary, endure the forces of inertia, translation, and rotation due to accelerations originating in the chamber of the piece.

For the purpose of showing the magnitude of these forces we will take as an example the shell of a cannon of 75. This projectile is subjected during firing to a minimum acceleration of the order of 200,000 meters per second. Its ratio to g (acceleration due to its weight) being about 20,000, it results that the particular material contained in the shell develops at the moment of firing under inertia an effect directed toward the base of the shell equal to about 20,000 times its weight.

The height of the shell cavity occupied by the charge being on the average about 20 centimeters, it follows, if we designate the specific

gravity of the explosive by δ, that the pressure in kilograms per square centimeter exerted by the charge on the base of the projectile is equal to $\frac{20\times\delta\times20{,}000}{1{,}000}$ which is 400δ. Taking δ as equal to 1.5, it results that the effort tending to crush the column of explosive as the projectile starts from rest proceeds in increasing progression from the point toward the base where in contact with the latter it amounts to 600 kilograms per square centimeter.

On the other hand, under the influence of the rifling the projectile acquires a motion of rotation whose maximum velocity at the instant of leaving the bore is about 300 revolutions per second, and this angular velocity corresponds to a circumferential velocity of the inside walls of about 50 meters per second.

These figures show the magnitude of the forces to which the explosive material of the charge is subjected depending on the duration of the blow from the cannon. It by this becomes obvious that a powerful explosive which has been used on a large scale in the mining industry and in rock work is nevertheless unfit for use in charging projectiles. However, we now know the precise conditions that an artillery explosive must satisfy.

Regarding these characteristics, the most important is that the force and rate of detonation shall be as large as possible. It has been observed that this last requirement implies the use of crystalline substances, but it should be stated that the realization of this desideratum is, notwithstanding, secondary, since experience has shown that a satisfactory detonation can be obtained with plastic substances if a detonator capable of imparting a sufficiently high velocity is used.

In order to insure safety in firing, the explosive should be capable of resisting the effects of inertia which are developed in the chamber of the piece. If it be a solid—and this is generally the case—it should be absolutely compact in structure and should adhere strongly to the walls of the shell.

The meeting of this last condition is necessary in order to prevent the friction of the charge resulting from a difference in speed of rotation between the shell and its explosive due to the inertia of the latter. The compactness of loading tends to prevent compression and shock on the interior of the explosive mass following the travel of the projectile through the bore. The adhesion of the explosive to the walls of the shell can be determined at the outset by following the method used in loading cartridges in which the explosive, instead of being placed directly in the cavity in the shell, is first enveloped in thin sheet metal or cardboard and, thus surrounded, is introduced into the chamber of the shell after the walls have been coated with

a layer of vaseline or paraffin. If the interior of the cartridge is firmly partitioned off by resistant diaphragms, these will also tend to protect the charge from the friction due to its inertia to rotation. The use of a simple cartridge in metal or cardboard appears to be advisable in all cases, but particularly for base-loading shells of large capacity.

It is possible to build up the charge by the aid of several separate cartridges and by this means avoid the difficulties encountered in seeking to obtain, through fusion, a long column of perfectly homogeneous explosive. In all cases this rids one of the serious inconvenience which results from the fused explosive running into the space between the projectile and its base plug. It also prevents dust from the explosive getting into the threads of the plug or into the fuse device.

If the explosive be formed by mixing a solid and a liquid, these will be found evidently the best conditions from the point of view of safety, since under these circumstances abnormal heating of an isolated point will be much less likely to occur and all friction of solid on solid will be avoided. But, on the other hand, another inconvenience presents itself, viz. J, the acceleration of translation to which the charge is subjected at the instant the projectile starts on its travel of the bore. It follows as a result of this acceleration that the difference between the apparent specific gravities of the solid and liquid components of the explosive is multiplied by J. There is then shown a tendency of the explosive to separate into its two components, following the axis of the projectile, at the moment of departure from the gun. In order for such an explosive to be acceptable it is necessary that the difference in the specific gravities of its components shall be as small as possible.

One may theoretically consider the uses of liquid explosives such as Sprengel's (dinitrobenzene and nitric acid, $F=9940$) or one of the panclastites of Turpin (nitrobenzene and hyponitrous acid; $F=10,860$; naphthalene and hyponitrous acid; $F=11,700$). In this case the question of safety on departure appears completely assured; but the intimate mixing of the components of the mixture will not be effected unless they are miscible.

2. PRINCIPAL EXPLOSIVES UTILIZED.

As a rule, up to the present, only those solid explosives composed of nitrated derivatives of the aromatic series have been used as charges for artillery projectiles.[1] It is expedient now to study the properties

[1] The Austrian artillery appears to have tentatively used the mixture of ammonium nitrate and aluminum known as ammonal, but the sensitiveness to percussion and friction of explosives having an Al base appears to have led to its discontinuance.

of those bodies that are utilized to-day, which are picric acid, trinitrocresol, trinitrotoluene, trinitronaphthalene, and the mixture of ammonium nitrate and dinitronaphthalene known as Favier's explosive. There will be added also some bodies of the same series which appear susceptible of use, but of which we have no example.

1. *Picric acid.*—Picric acid or trinitrophenol (melinite, lyddite, schimose) occurs in small yellow crystals which possess a strong coloring power. It is but slightly soluble in water at ordinary temperature, but this solubility increases as the temperature is raised. It is readily soluble in acetone. Melinite is fused at about 122° C. Its reactions are acid and it forms with metals (save tin) crystalline salts of marked color. Speaking generally the picrates are markedly explosive and they are the more unstable the heavier the metal which enters into their constitution. Lead picrate is especially dangerous. Iron picrate is much less so and its explosion in use can not occur if the explosive is moist. In order to prevent its formation the walls of the projectiles are so varnished or coated with plating as to prevent their direct contact with the explosive.

It follows that because of the dangerous character of the lead picrate the tin used with which to coat the walls of the shell should be extremely pure. The care to be taken in avoiding, in the course of charging, the production of picrates is of the first importance and it is not to be overlooked as a factor in deciding against picric acid in comparison with those which follow it.

Picric acid may be detonated in several ways. That detonation of it which is called "complete" is characterized by the production of dense black fumes holding free carbon in suspension in them. In the detonation styled "incomplete" the explosion gases have a greenish-yellow color and at the same time they deposit a layer of undecomposed explosive on the surrounding objects. The energy set free in the complete is greater than in the incomplete detonation.

The reactions attending these two methods of detonation are approximately as follows:

Complete detonation $2C_6H_3(NO_2)_3OH \rightarrow 8CO + 3CO_2 + 3H_2 + 3N_2 + C.$

Incomplete detonation $2C_6H_3(NO_2)_3OH \rightarrow 11CO + CO_2 + H_2O + 2H_2 + 3N_2.$

It is evident that in the case of a reaction effected by detonation in an extremely resistant envelope the consideration of the products will, in virtue of the displacement of the equilibrium, give principally those shown in the first equation.

Admitting there is obtained under an infinite pressure the maximum condensation represented by the equation

$$4C_6H_3(NO_2)_3OH \rightarrow 14CO_2 + 3CH_4 + 7C$$

the corresponding potential equals 573^{Tm} which is much in excess of that characterizing the first reaction given above. These reactions correspond in effect to the following:

Complete detonation.	Incomplete detonation.
V_0=329 liters.	677 liters.
t=2,832° C.	2,634° C.
F=9,780.	9,682.
d=0.837.	0.877.
Potential=371 ton meters.	323 ton meters.

The velocity of detonation of cores of melinite inclosed in lead or tin envelopes is about 7,000 meters per second. Dautriche, with very powerful primers, has obtained a velocity of 7,645 meters per second.

Although the properties of fused picric acid were known before the time of Turpin, yet it is to this inventor we owe its utilization as a military explosive. Turpin has devised that form and disposition of detonator which has insured its complete detonation. His process consists essentially in causing the mercury fulminate detonator to act on pulverulent picric acid. The detonation of this last brings about the detonation of the fused explosive.

We have seen that the strong adhesion of the charge of explosive to the walls of the projectile is an essential condition to security in firing. From this standpoint melinite is above all most satisfactory. It is estimated that more than 20 kilograms per square centimeter of effort is necessary to effect the separation of a mass of melinite from the metallic walls to which it has been fused. This adhesion appears to increase markedly for some days after fusion. It is always greater than the cohesion of the explosive.

The fusing of the explosive in order to run it into the projectile is generally effected in a water bath which is a thermosiphon. Since melinite increases in volume at the moment of solidification, experience shows that, as a consequence, cavities may be formed in the interior of the charge of the projectiles. Practice has supplied suggestions by which this serious defect may be overcome. An essential precaution consists in preventing the presence of the melinite in the thread of the nose fuse. Its presence on the outside of the fuse or in its threads may cause a premature explosion.

Picric acid is obtained by nitrating phenol. To obtain a uniform product, the crystalline phenol should fuse at 39° C. This substance is obtained in the distillation, between 150° and 200° C., of gas tar. It can be obtained synthetically through the oxidation of benzene, the series of operations being as follows: The benzene is treated at first with concentrated sulphuric acid. Milk of lime is added in excess to neutralize the acid. The solution is then treated with sodium carbonate to form the sodium-benzene-sulphonate ($NaSO_3C_6H_5$). This is evaporated to a sirup with addition of

soda and fused, when sodium phenolate is formed which is decomposed with sulphuric acid to set the phenol (carbolic acid) free, which is separated by ether and purified by distillation.

This purified phenol is treated with 66° B. sulphuric acid and then with 37° B. nitric acid. The picric acid formed is purified by repeatedly washing it with water and draining.

2. *Trinitrotoluene* (*tolite*, *trotyl*).—This body appears in the form of small yellow crystals which fuse about 81°. Though insoluble in water, it is very soluble in benzene and toluene.

While melinite reacts markedly, acid trinitrotoluene is completely neutral. It does not therefore act upon the metals in which it is put. It is more agreeable than melinite to handle since its dust is not irritating. It is less sensitive to shock but is also a little less powerful than picric acid (F=8,080). When fused it adheres strongly to the walls of the vessel in which it is contained. But tolite presents the disadvantage of "piping" markedly at the moment of solidification. Its rate of detonation is about 10 per cent less than that of picric acid.

Tolite is usually prepared by trinitrating toluene directly with a concentrated sulphuric-nitric acid mixture. The reaction begins at 40° and ends at 105°; it being heated from five to six hours.

Tolite is primed in the same manner as melinite, but it detonates violently in the open air under the influence of a mercury fulminate detonator only. It is employed in the manufacture of cordeaux detonants by inclosing in lead tubes. It is the explosive most commonly employed by the Germans in charging their projectiles.

3. *Nitrocresols* (*cresylites or cresylol commercial*).—Cresol is a product of tar distillation which is obtained between 185° and 210°. It is a mixture of three isomers, the proportions of which are very variable. Cresol is nitrated just as phenol is but the trinitrocresol only is used, and this is really the trinitrometacresol which possesses properties analogous to those of picric acid. It is a yellow substance which in all regards is more disagreeable to handle than picric acid, for its dust is more irritating and its vapors more suffocating. Its process of manufacture is similar to that of picric acid.

As an explosive it is a little less powerful than melinite. This is easily understood when we recall that it contains a large excess of carbon and hydrogen and that its combustion is consequently less complete. Mixed with pure melinite in the proportions of 60 per cent trinitrocresol to 40 per cent picric acid, there is obtained the explosive known in France as cresylite 60/40. This mixture, which is obtained by fusion under water, melts at about 85°, but at 65° it is sufficiently plastic to permit of its being compressed into charges which, on cooling, are compact, amorphous, and very homo-

geneous. Charges are thus obtained which are free from piping. It is this valuable property which justifies the use of the nitrocresols in charging projectiles.

In spite of the fact that cresylite 60/40 has less force (8,330) than picric acid, its rate of detonation (7,485 meters per second) is practically the same as the latter.

Like the trinitrophenol the trinitrocresol has an acid function. It forms salts analogous to the picrates and these are explosive. The ammonium cresylate only is sufficiently insensitive to shock to permit of its military use. In Austria it has been used in charging shell under the name of *ecrasite* and its power, though inferior to that of melinite or cresylite, is superior to that of dynamite No. 1.

4. *Trinitronaphthalene or naphtite* ($C_{10}H_5(NO_2)_3$).—Trinitronaphthalene is a clear yellow substance which is only slightly soluble in water, but is soluble in acetic acid and chloroform. Its sensitiveness to shock is very much less than that of melinite but it requires a very powerful detonator with which to effect its detonation. When ignited it burns, without explosions, with a smoky flame, and it resists the shock of impact of small-arm projectiles.

It is prepared by nitrating the mononitro or dinitronaphthalenes as a mixture of three isomeric trinitronaphthalenes which fuse about 110°.

At present naphtite is but little used as shell charges because of the difficulty of detonating it as mentioned above. It, however, is a powerful explosive, which, exploded in a bomb under the density of loading of $\Delta=0.3$, gives a pressure of 3,275 kilograms per square centimeter.

5. *Favier explosives and schneiderite.*—The Favier explosives have an ammonium nitrate base to which a slightly nitrated hydrocarbon (which is therefore but slightly explosive) is added. The ammonium nitrate itself being an explosive which is quite insensitive, the mixture obtained is remarkably insensitive, but its ignition temperature is relatively quite low. This union of properties explains its employment in coal mines as a safety explosive. The mixture of ammonium nitrate 90 per cent with mononitronaphthalene 10 per cent, constitutes schneiderite employed at Creusot for filling shell. It is a powerful explosive which is characterized by a force of 8,400 units and a potential of 415 ton meters. Its normal rate of detonation, as determined by M. Dautriche, was 3,585 meters per second for the pulverulent explosive.

It has been said above that Favier explosives are but very slightly sensitive to shock and thus schneiderite has been found to resist the impact of a projectile or the blow from a very heavy weight and, when placed on the rail, a cartridge of this substance was not ex-

ploded by the passage of a train. These properties imply the necessity of using a very powerful detonator with which to provoke its detonation.

6. *Benzite* ($C_6H_3(NO_2)_3$).—Benzite or trinitrobenzene is a white crystalline body which, when pure, fuses at 121°–122°. Although as powerful as melinite[1] it is very much less sensitive to shock than the latter. Moreover, it does not attack metals and, when compressed, it acquires a density of 1.67. Finally its rate of detonation, of the order of 7,000 meters per second, is equal to that of picric acid.

Trinitrobenzene is an extremely interesting body because of its various properties. Unfortunately its price is so high as to limit its use. Thus far it has not been employed except to lower the melting point and increase the plasticity of tolite.

It is prepared by oxidizing trinitrotoluene with potassium dichromate in sulphuric acid solution by which trinitrobenzoic acid is formed, and this on treatment with boiling water splits off the CO_2 group yielding the trinitrobenzene. The chrome alum formed, and which remains in the sulphuric acid liquor, is recovered by concentration and crystallization and is again converted into the dichromate.

7. *Nitro derivatives of aniline.*—Aniline ($C_6H_5NH_2$) is capable of furnishing a series of explosives that may be employed in charging projectiles. We will examine some of the more interesting of them.

The tetranitraniline appears as a crystalline body very similar to picric acid. It is prepared by heating the metanitraniline at 80° with concentrated mixed acids. It is an extremely powerful explosive, very stable and contains 25.6 per cent of nitrogen. Its absolute density, 1.867, is relatively very high. It is partially decomposed on heating at a temperature which depends on the manner in which the increase in temperature in a given time has been effected. Thus, if the rate of increase is 5° per minute the decomposition begins at 216°–217°. This does not give rise to explosion. While insoluble in water at ordinary temperatures, it is very soluble in acetone. It does not attack metals. By reason of this assemblage of properties tetranitraniline appears to be most advantageous for use.

Another nitro derivative of aniline which is equally interesting from our standpoint is tetryl. This body which is tetranitromethylaniline ($C_6H_2(NO_2)_3NNO_2CH_3$) contains 24.2 per cent of nitrogen. More powerful than guncotton or melinite it is less so than tetranitraniline. According to Lieutenant Colonel Koehler its heat of

[1] According to M. Dautriche, the power of benzite is 5 per cent greater than that of picric acid.

formation is—40.8 cals. Hence tetryl is an endothermic compound and this explains in part the power of this explosive. It is easily prepared by acting on methylaniline sulphate with mixed acids. It appears at present to be used only in the manufacture of cordeaux detonants. Many of the properties it exhibits tend to show it to be well fitted for use in shell charges. We may note, however, that its price, as well as that of the preceding explosive, is greater than that of picric acid.

GOLD AND SILVER DEPOSITS IN NORTH AND SOUTH AMERICA.[1]

By Waldemar Lindgren, *Boston, Massachusetts.*

I. Introduction.

At the time of the discovery of America the Old World had a scant supply of the precious metals. Both the northern and the southern parts of the new continent proved wonderfully rich in gold

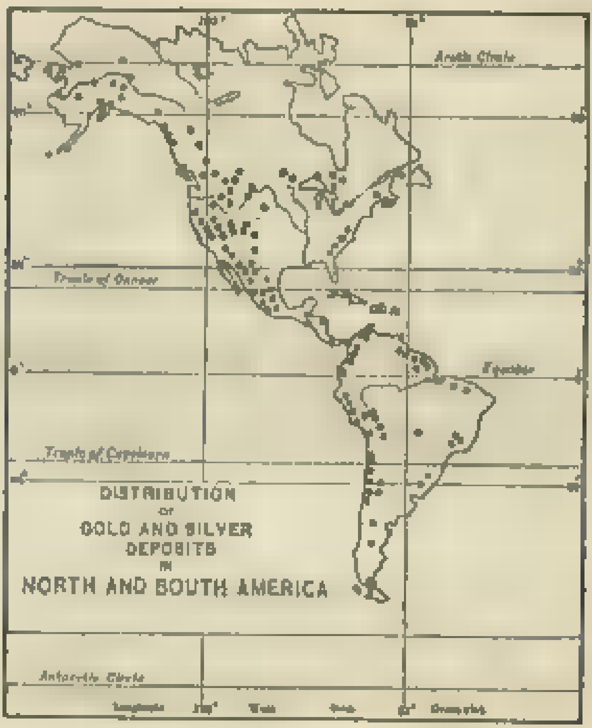

Fig. 1.

and silver, and its treasures were eagerly looted; though the looting has lasted four centuries, the mines of its mountain chains are far from being exhausted. Even the later discoveries in Australasia and

[1] Read at the Second Pan-American Scientific Congress, Washington, District of Columbia, Jan. 8, 1916, and at the Arizona meeting, September, 1916, of the American Institute of Mining Engineers. Reprinted by permission from transactions of the Institute, Vol. 55, pp. 883–909 (1917).

eastern Siberia could not rob the Western Hemisphere of its position as the greatest gold and silver producing region of the world, though finally the developments in a narrow and circumscribed area in South Africa wrested from the Americas their supremacy in the production of gold.

Nevertheless, the history of the two parts of the great western continent has been strikingly different. At first the Spaniards extracted vast treasures of silver from Mexico, Peru, and Bolivia, while Colombia and some placer deposits in Peru yielded a smaller quantity of gold. A couple of centuries later a stream of gold began to flow from Brazil, the silver production from the countries mentioned above continuing strong in the meanwhile. Later on, the yield of South America diminished, but to offset this there began a wonderful series of discoveries in North America. The gold fields of California astonished the world; and when the cream of these had been skimmed off there began a no less amazing development of the central cordilleran gold and silver districts, which soon made the United States the greatest producer of the precious metals. Aided by ever improving technique, extensive exploration, and a system of railroads, the yield was maintained and increased. Still later followed the discoveries of the gold fields of the arctic region and silenced those who had maintained that the zenith in gold production had passed. Recently the Province of Ontario in eastern Canada rose unexpectedly with offerings of the richest silver ores the world has known, and with new and at first doubtfully accepted gold fields.

Chile and Bolivia in the middle of the last century added some rich silver mines to their long list of mining districts, and later placer gold began to be extracted in large quantities from the Guianas, but on the whole no such sensational finds were made in the southern continent as had marked the recent history of the northern part, and in many regions the mining of the precious metals fell into a rut, the production being barely maintained or diminished slowly. The latest events indicate an awakening, and a stimulus under the influence of which the production of South America is gradually increasing. Large amounts of silver are extracted from copper ores by operations on a large scale, and dredges dig up the gold of Colombia and Tierra del Fuego.

It can not be doubted that the total yield of the northern continent of gold and silver is larger than that of the southern part. A glance at the table in the Appendix will show that this difference is strongly emphasized at the present time. During the last decade the gold production of North America had a value of $1,838,268,000, while South America yielded only $125,000,000. For silver, South American statistics are in less satisfactory shape, but the compilation shows that while in 1913 North America produced this metal to the

value of $99,476,400, South America's mines yielded less than one-tenth of this huge sum. Figure 1 shows the approximate distribution of the gold and silver deposits of the two continents.

There are no better prospectors in the world than those of some South American countries, and we may rest assured that a great percentage of possible discoveries has already been made. Yet no one who has studied South American mining districts can fail to see the possibility of a more extended production than at present, even while realizing the difficulties of climate, altitude, transportation, and lack of adequate available capital.

The purpose of this paper is to call attention to the geological features that govern the distribution and richness of the precious metal deposits of South America, to compare them with those of North America, and to classify them according to geological affiliation.

II. GEOLOGICAL FEATURES.

A slight acquaintance with the geographic features of the two parts of the American Continent suffices for the realization of their essential similarity. The two land masses, elongated from north to south, have a wide eastern part occupied by fertile plains, hilly country or low mountain ranges, and a narrower western part, with the rough topography of an almost continuous high mountain chain closely following the Pacific coast, narrow in South America, broadening in North America. This is one of the great earth features, and is known as the American Cordillera. In South America it is also known as the Andes. Considered on a large scale, its build is simple, though in detail it is diversified by two or more parallel ranges, by intermontane high plateaus or valleys, and by volcanoes, many of which are active.

To the geologist this difference of east and west is sharply accentuated, for he knows that the Atlantic side represents the area of quiet where strong mountain-building forces have rested for millions of years—since the close of the Paleozoic era—while the leveling agencies of erosion and sedimentation have been at work. He knows that the western margin marks the long strip of weakened earth crust along which tangential stresses have played since early Mesozoic times. These stresses culminated in the early Tertiary times, causing folding and violent thrust faulting, as if an irresistible force had forced a wrinkle in the earth's crust eastward. These cordilleran disturbances reach their maximum along the inner eastern edge of the chain. To some degree they still continue, accompanied by uplifts and depressions. Lava flows have been poured out in great volume from volcanoes along the Cordilleras, especially on the western side, and this has continued at least from the early Mesozoic to

the present time. At the same time masses of molten rock have been forced up from great depths into the rocks nearer the surface, and cooled there to granites and diorite porphyries without ever reaching the surface, though through gradual wearing away of the covering rocks many such masses are now exposed at the surface.

Almost all primary gold and silver deposits have been formed during or shortly after epochs of volcanic or intrusive activity. Secondary deposits are derived by the disintegration and concentration by water of such primary deposits. They are called placers or alluvial deposits and are usually cheaply and easily worked.

On the American Continent the primary gold and silver deposits date from two widely separated ages. The first period is geologically very ancient and belongs to the pre-Cambrian or early Paleozoic; its deposits are thinly scattered over the entire continental area, but are at many places covered by later rocks. The second period is much more recent, and belongs to the late Mesozoic and the Tertiary. Its numberless deposits were formed during the great igneous activity which accompanied the building of the Cordilleras and are thus confined to the western or cordilleran part of the continents in which area the deposits of the older period are rare because capped by later sediments or flows.

Placers may be formed from deposits of either period.

I. DEPOSITS OF THE EARLY PERIOD.

Naturally, the deposits of the early period are best observed in the great eastern expanse of the continents where the early rocks are often splendidly exposed. Gold is the principal metal and is always accompanied by quartz gangue. The deposits bear evidence of having been formed at considerable depth and high temperatures. While the majority of these occurrences are poor, yet great richness may be found in small areas, and the purity and coarseness of the gold is favorable to the formation of placers, especially in temperate or warm climates. Wherever continental ice sheets have covered a region, as in Canada, they have almost invariably ground up and scattered the placers.

NORTH AMERICA.

In North America deposits of this kind are formed in the southern Appalachian States, in South Dakota, in Quebec, in Nova Scotia, and in Ontario. In the latter Province the recently discovered Porcupine district presents a case of extraordinary richness, the annual production being now over $4,000,000. The celebrated Homestake mine in South Dakota is working on a pre-Cambrian replacement deposit in form of thick lenses of altered schist with free gold. While containing only about $4 per ton, the ores yield annually over $5,000,000.

A number of scattered deposits of this kind are found in the cordilleran region of the United States, but they contribute only small amounts to the total production. The most important occurrence is the copper deposit of the United Verde mine in Arizona. Its copper bullion yields a considerable amount of gold and silver.

Compared to the deposits of the cordilleran or younger period in North America the yield—both total and annual—is small. Out of an annual gold production of about $130,000,000, the sum to be credited to the old group of deposits is at present (1913) not more than $10,000,000.

Very little silver is obtained from the gold deposits, but a small amount comes from the copper deposits of the Lake Superior districts. Until the discovery of the Cobalt district in Ontario the proportion of silver in the eastern region to the total output was even smaller than that of gold; but the native silver yielded by the deposits of this district (of a type almost unique in America) has changed this so that the old deposits of the East are now credited with about 800,000 kilograms out of an annual production for North America of over 5,000,000 kilograms. The great output of the Cobalt district emphasizes again how highly the precious metals may be concentrated Pampas formation or by lavas of the same age.

SOUTH AMERICA.

In South America we find extremely similar geological conditions, but here the older group of deposits yields decidedly more gold than that furnished by the belt of the Andes. On the other hand, the silver production of the older deposits is insignificant. A somewhat more detailed review will perhaps be acceptable. Figure 2 shows the distribution of the deposits in South America.

Gold deposits of the older type are known from Venezuela, the three Guianas, Brazil, Uruguay, and Argentina. Except in the Guianas they do not form continuous belts, but rather a series of scattered occurrences separated by barren ground or by younger transgressing fluviatile or marine deposits. South of the latitude of Buenos Aires the deposits, if existing, are covered by the Tertiary Pampas formation or by lavas of the same age.

The northeastern region extends 650 miles from the Yuruari Basin in eastern Venezuela to the Franco-Brazilian border of the Guianas. The occurrences worked are mostly placers, to the formation of which the conditions are very favorable; but quartz veins or mineralized dikes have also been exploited. The best example of the veins is furnished by the great Callao mine in Venezuela, which, during its life of 30 years (1865–1895), is said to have yielded $28,000,000 in coarse gold. Active exploitation of the placers and some veins is going on in the three Guianas at present, the French colony

yielding the greatest amount. In 1912 the production of this belt was about $5,000,000 and for the last decade it has not been less than $4,000,000 in any one year.

The primary veins from which the placers have been derived are contained in pre-Cambrian schists, diorites, diabases, granites, and granite porphyries.

The gold belt seems to continue to the southeast beyond the boundaries indicated, for it is reported that gold occurs in the Provinces of

Fig. 2.

Para, Maranhao, and Ceara, in Brazil, beyond the delta of the Amazon River. To the south follows a broad, barren interval until we come to the gold deposits of southern Brazil, in the States of Bahia, Minas Geraes, Sao Paulo, Parana, and Rio Grande do Sul. Of these the State of Minas Geraes is by far the most important. Even in the far western part of Brazil, at Cuyaba in Matto Grosso, occur placers said to be derived from older deposits similar to those of Minas Geraes.

It is almost forgotten at the present time that the placers of southern Brazil yielded heavily in the eighteenth century, particularly from 1700 to 1775, and this production was particularly welcome at a time when the gold from the Americas seemed exhausted and the treasures of the northern Cordilleras were as yet undreamed of. During the period named, these placers yielded from $1,000,000 to $2,000,000 annually. The total yield during the eighteenth century is variously given from $200,000,000 to much higher figures. After this period the production languished, but a few quartz mines continued to be operated and a little placer gold was washed. At the present time Brazil maintains its output of gold at from $2,000,000 to $3,800,000, but this is practically derived from three deep mines in Minas Geraes, of which the Morro Velho is the most important, besides having the distinction of being the deepest mine in the world (vertical depth 6,200 feet).

The deposits are quartz veins of a deep-seated type, allied in places to pegmatite dikes. They occur in part in Archean schists, gneisses, and granites, but most of them are found in a thick sedimentary series of schists and quartzite, which is older than the Cambrian but overlies the Archean. This series contains no intrusives, except some pegmatite dikes, and the Brazilian veins are in this respect markedly different from most other pre-Cambrian occurrences. It is believed that igneous intrusions took place in the rocks underlying the pre-Cambrian sediments and that only pegmatitic dikes and quartz veins reached up into the covering series.[1]

Similar geological conditions prevail in Rio Grande do Sul, beyond which the gold-bearing region continues into Uruguay, where the most southerly mines are found near Cunapiru. Uruguay yields annually up to $100,000 in gold.

The most southerly representatives of this older class of gold deposits appear in the Sierras of the pampas, for instance, in that extending from San Luis to Cordova in Argentina. The old crystalline schists, granites, and pegmatites here emerge from under the pampas formation and the Permo-Triassic beds, and contain deposits of tungsten, gold, and silver, but the latter two metals are not present in quantities sufficient for economic mining.

While it is possible that some deposits of this kind occur in the pre-Cambrian of the Andean region, which is exposed in Colombia and in the northernmost provinces of Argentina, it is improbable that they contribute perceptibly to the total production.

To sum up: The old gold deposits yield the total production of Venezuela, the Guianas, Brazil, and Uruguay and at the present

[1] E. C. Harder and C. K. Leith: The Geology of Central Minas Geraes, Brazil (Journal of Geology, vol. xxiii, pp. 341 to 378, 385 to 424 (1915)).

time contribute to the gold production of South America about $8,500,000, or not far from the amount extracted from the same class of deposits in North America.

2. DEPOSITS OF THE LATER PERIODS.

GENERAL FEATURES.

From Cape Horn to Alaska the gold and silver deposits of the cordilleran belt are formed under similar geological conditions, and are of the same general geological age. It has already been emphasized that they are products of the igneous activity which has accompanied the rise of this gigantic mountain chain.

They were formed within several epochs, but all of them lie between the earliest Cretaceous and the present; that is, they are late Mesozoic, Cenozoic, or Quaternary in age. They were formed, on the whole, nearer to the surface than the old deposits of the pre-Cambrian, or at least under conditions of more moderate temperature. Many of them, indeed, were formed very close to the present surface. Following intrusions or lava flows, hot waters loaded with gases and metals of igneous origin rose toward the surface, and, in cooler regions of the crust, deposited their load of metals. In part the gold and silver occur in minute quantities associated with copper and lead minerals, and are recovered from the base bullion. Much silver is obtained in this manner, but most of the gold is derived from gold quartz deposits, properly speaking, or from placers caused by the wearing down by erosion of these deposits.

NORTH AMERICA.

It is difficult indeed to give in a few paragraphs even an approximate idea of the gold and silver deposits of the North American cordillera. The annual yield of the region is enormous, attaining now $130,000,000 in gold and nearly $100,000,000 in silver.

A great gold-producing belt lies along the Pacific and reaches from California to Alaska, with local interruptions. These are the oldest deposits of early Cretaceous age and they have yielded vast placer or secondary deposits. The annual production, including the placers, is not less than $40,000,000. Geologically they are connected with the intrusion of dioritic rocks, an intrusion extending like a gigantic dike along the Pacific coast mountains.

Throughout the interior part of the cordilleran region are numberless smaller intrusions of granitic or dioritic rocks, or of the porphyries of these rocks, most of them of earliest Tertiary age, some a little earlier, others a little later. Aureoles of gold and sil-

ver veins surround these intrusions, and contribute from numerous centers in the interior cordilleran region to the total production.

Contact-metamorphic deposits, formed where limestone beds have adjoined the igneous contacts and absorbed the emanations from the intrusive magma, add their smaller share to the precious metal production, but are usually richer in the base metals.

Lastly we have a remarkable type of veins, which occur in lava flows near volcanic vents, and which were formed near the surface by hot springs charged with emanations from the molten rocks. These deposits are often wonderfully rich, both in gold and silver. They are the "bonanza" deposits proper; the Comstock, Tonopah, Goldfield, and Cripple Creek are among the more celebrated localities of such veins; few of them are found north of the Canadian boundary and none of them along the main Canadian or American coast, but they are best represented in Nevada, Arizona, Utah, and Colorado. In the United States they yield not less than $30,000,000 a year.

Going farther south we enter the great mining region of the Mexican plateau. For nearly 400 years an unceasing stream of silver has been poured out of the mines of Mexico, and at the present time the country produces annually about 2,000,000 kilograms, or 64,000,000 ounces of that metal.[1] Igneous rocks, both flows and intrusions, abound in Mexico, and practically all of the deposits are of latest Cretaceous or of Tertiary age, thus on the whole more recent than any of those of Canada and the United States.

The most celebrated silver mines are of the type formed in or near volcanic flows near the surface. We need cite only Pachuca, Guanajuato, and Zacatecas; but there are hundreds of other similar districts. Of late the annual gold production has risen sharply to $20,000,000 or $25,000,000; part of this comes from silver or base bullion, but the greater part is derived from veins in volcanic rocks similar to those just described and situated at El Oro, in the State of Mexico. It should not be overlooked, however, that there are also in the Cretaceous limestone countless though small intrusive masses of diorite or porphyries around which auriferous or argentiferous veins or contact-metamorphic deposits have formed, and which contribute their share to the production.

THE ANTILLES.

Evidences of a feeble mineralization are found in Cuba, Haiti, Porto Rico, and Jamaica and more or less placer gold was obtained, particularly during the sixteenth century from the first three islands

[1] The total production of silver in Mexico is estimated as 122,500 metric tons, a quantity far greater than that yielded by any other country in the world. (See Beyschlag, Krusch and Vogt (Die Lagerstätten, vol. II, p. 60 (Stuttgart, 1912)).

named. Even now 100 ounces or so are washed annually from the rivers of Porto Rico and perhaps the same amount from those of Haiti. The gold seems to be derived from the vicinity of intrusives such as diorite and serpentine, in part, if not altogether, of post-Cretaceous age. The gold placers of Cuba were situated in the middle part of the island, in the Santa Clara and Puerto Principe Provinces. Those of Haiti are said to have been highly productive in the early days of the Spanish régime.

CENTRAL AMERICA.

The Cordillera does not continue as an unbroken chain from Mexico into Colombia. The structure of Central America is complex, with short easterly trending ranges of older rocks in Guatemala and Honduras. Farther south these older rocks are submerged beneath Tertiary and Recent lavas, in part andesitic. The Isthmus connecting the two Americas is in fact marked by a chain of volcanic cones, many of which are active.

Though some mineralization is found in the older rocks of pre-Tertiary age, the valuable deposits are mainly in andesitic or rhyolitic rocks, and belong clearly to the class of veins which were formed near the surface. Some of these yield mainly gold, but in many cases they are of the well-known type in which gold and silver occur together without notable amounts of the baser metals. The annual production of Central America ranges from $1,500,000 to $4,500,000 in gold and from 50,000 to 75,000 kilograms of silver.

Guatemala contributes but little, though there are many prospects and placers on Motagua River on the Atlantic side.

Honduras has the reputation of great richness. Its placers of Olancho and Choluteca were worked by the early conquerors. At present the greatest part of its production comes from the gold-silver mine of Rosario near Tegucigalpa. The Republic is the largest silver producer in Central America. Gold to the value of about $600,000 is produced annually in each of the three States, San Salvador, Nicaragua, and Costa Rica. In Nicaragua rich placers have been worked in the Prinzapolca and other Caribbean rivers, and the gold mining district of Pis-pis in the northeastern part of the Republic has lately attracted much attention. Costa Rica has had a considerable production from the placers of Monte Aguacate. The Abangarez and Montezuma lode mines, on the Pacific side, are now the chief producers. In San Salvador the production comes largely from the Butters mines. All of these veins appear to be contained in andesite or rhyolite.

We find the same condition in Panama, though at present there is little production from this State. The Espiritu Santo mine at Cana

near the Colombian boundary has been worked from the seventeenth to the twentieth century and the deposit is contained in Tertiary andesite.[1]

THE SOUTH AMERICAN CORDILLERA.

General features.—From Cape Horn to Colombia the South American Cordillera or Andes forms a continuous chain closely following the coast. Its width ranges from 100 miles near Magellan Strait to 500 miles in the latitude of Bolivia. North of Bolivia it again contracts to a width of about 300 miles. It is thus, considering its length, a narrow mountain chain, but nevertheless generally made up of three longitudinal units. In the north they are known as the eastern, central, and western cordillera or by other local names. In Peru they are spoken of as the Coast, Sierra, and Montaña regions, the last being the eastern slope of the Andes. In the south there are locally four subdivisions—the coast range, the western and the eastern cordillera, and the pre-Cordilleras or front ranges. Between the eastern and western range lies, in Bolivia, the high plateau or "Altiplanicie." In places, as in northern Chile and Bolivia, the western range itself partakes of the character of a plateau.[2]

Two ranges stand out by reason of great altitudes, both being rich in mineral deposits. One is the Sierra Blanca of northern Peru, in the western cordillera; the other is the Cordillera Real of eastern Bolivia which includes the high summits of Sorata and Illimani.

III. GEOLOGY OF SOUTH AMERICA.

INTRODUCTION.

It will be admitted that it is no easy task to condense in a few pages what is known of the geology of a continent; and for the imperfections and omissions in this account I must therefore ask the indulgence of the reader.

Broadly speaking, the most prominent formations of the Andes are the Cretaceous sediments, which extend almost without interruption from northern Colombia to Tierra del Fuego. Of scarcely less importance though smaller in area, are the Tertiary and Recent lava flows and the intrusive masses of early Tertiary age. No great intrusions of Cretaceous age appear to exist in South America, although the volcanic activity in the Jurassic and Cretaceous was intense and yielded heavy masses of lava flows intercalated in these formations.

[1] Malcolm Maclaren (Gold, London, 1908).

[2] Isaiah Bowman: Physiography of the Central Andes (American Journal of Science, 4th ser., vol. xxviii, pp. 197 and 373 (1909)).

As far as known, the pre-Cambrian is only exposed in the north and on the Argentine side of the Bolivian high plateau.

COLOMBIA AND ECUADOR.

The work of W. Sievers, A. Hettner, A. Stuebel, and Theodore and W. A. Wolf permits a general view of the geology of these countries. As already emphasized, the Andes of Colombia, divided into three chains, do not continue toward the Isthmus, but bend eastward toward Venezuela. The coast, both in Colombia and Ecuador, is occupied by Tertiary strata. The Cordilleras consist in general of a core of crystalline schistose rocks which are generally referred to the pre-Cambrian. Above these there is a great break in both countries: The Paleozoic and the early Mesozoic apparently are missing. Instead, the Cretaceous overlies the schists and the extensive beds are divided into the Lower and Upper, the latter being overlain by the Guaderas beds, probably also Cretaceous. There was no marked folding during the Cretaceous. Quartz monzonites and allied rocks are reported from many places; they are older than the Tertiary and younger than the Upper Cretaceous. Flows of "labradorite porphyrite" and tuffs are embedded in the Cretaceous.[1]

The Cretaceous is unconformably overlain by the Tertiary. Latites and tuffs represent the volcanic activity of the early Tertiary, continued by the ejectamenta of a series of recent volcanoes, most strongly represented in Ecuador.

A sketch map of the general geology of Ecuador, by W. A. Wolf,[2] shows similar conditions. There is a broad belt of Tertiary beds along the coast adjoined by a narrow belt of Cretaceous with associated eruptives. Then follows the volcanic belt, Quito being placed at its eastern margin, and the main cordillera east of that city is built of granite and crystalline schists, all probably pre-Cambrian.

PERU.

Much information on the geology of Peru is contained in the publication of the Cuerpo de Ingenieros de Minas at Lima, which include also some of the important writings of Prof. G. Steinmann. The results refer mainly to the western and central cordillera, and the geological features of the Montaña slope, clad in tropical vegetation, are as yet little elucidated.

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[1] E. Lehmann: Beiträge zur Petrographie des Gebietes am oberen Rio Magdalena (Tschermak's Mineralogische u. Petrographische Mitteilungen, vol. xxx, pp. 225 to 280 (1911)).

[2] Sketch of the Geology of Ecuador (condensed in Mining and Scientific Press, vol. cv, No. 4 (July 27, 1912)).

Steinmann's profiles[1] from the Pacific to Rio Marañon show 180 kilometers of Upper and Lower Cretaceous beds with interbedded volcanics, strongly folded and in part overturned toward the east, There are in these Cretaceous rocks numerous early Tertiary intrusions of granodiorite and porphyries ("Andesitische Tiefengesteine"), but few of them are more than 10 kilometers in width. In the valley of the Marañon, old ("pre-Devonian") schists and granites appear for the first time and probably form the continuation of the pre-Cambrian of Colombia and Ecuador. The porphyritic intrusions are extremely numerous, and Steinmann refers to them as "laccoliths," though usually they have a vertical attitude, conformable to the surrounding sediments. Farther south the granodioritic batholiths become even more abundant, one exposed in the Rimac River being 50 kilometers in width. They always metamorphose the surrounding Cretaceous limestone.

BOLIVIA AND SOUTHERN PERU.

A section across this region, recently described by J. A. Douglas,[2] is 330 kilometers long, but does not include the whole of the montaña slope. Here the Andes are divided into the western cordillera, the Bolivian high plateau or the "Altiplanicie" and the eastern cordillera or the Cordillera Real. The latter includes the highest summits, Illimani and Sorata, but contains no volcanoes or large masses of volcanic rocks. It is largely built of older Paleozic sediments (Cambrian, Ordovician, Silurian, and Devonian), mostly slates and sandstones, and these are intruded by masses of granite, diorite, and porphyries. The Upper Devonian and the lower Carboniferous are both absent.

In the Altiplanicie we find the same folded Paleozoics, with transgreding Cretaceous in part terrigenous sediments, such as those of Coro-Coro. The Cretaceous is covered by post-Miocene andesites.

The western Cordillera along this section is essentially a volcanic range with numerous dormant or extinct volcanoes, and vast accumulations of lavas, including rhyolite, trachyte, and andesite.

Underlying these rocks and beautifully exposed along the Chilean coast as far north as Arica are Jurassic and Cretaceous strata interbedded with contemporary lavas and intruded by early Tertiary granular rock. The latter range from quartz monzonite to quartz diorites, and are accompanied by pegmatite dikes, many of which carry tourmaline. These intrusives are best exposed in the canyons.

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[1] Gebirgsbildung und Massengesteine in der Kordillere Südamerikas (Geologische Rundschau, vol. 6 Fas. 1–3, 1910). Ueber gebundene Erzgänge in der Kordillere Südamerikas (International Mining Congress, Düsseldorf, 1910).

[2] Section across the Andes in Peru and Bolivia (Quarterly Journal of Science, vol. lxx, Pt. 1, pp. 1 to 53 (1914)).

Douglas regards the intrusive rocks of the eastern cordillera as post-Devonian and pre-Jurassic in age; but this is apparently not proved, some authors calling them early Tertiary.

CHILE.

Conditions similar to those just described prevail in Chile. We find here, however, a coast range of lower elevations, largely made up of Mesozoic sediments with interbedded volcanics and a main western range, plateaulike in the north, which is surmounted by a long line of active volcanoes and often really constitutes the western margin of the Altiplanicie. The basement on which the volcanic cones rest is largely of Mesozoic sediments, more or less abundantly intruded by granodioritic rocks. South of Concepcion the intrusive granitic rocks increase in volume and are bordered on the west by metamorphosed sediments of doubtful age in Chiloe Island and the Taytao Peninsula. Quensel's[1] researches have shown that a vast body of quartz dioritic intrusive, similar to the batholith of British Columbia, but of greater length, follows the coast from Puerto Montt down to the extreme tip of the continent.

On the east side this batholith is almost continuously adjoined by Mesozoic sediments[2] in which great flows of "quartz porphyry," "porphyrites," and their tuffs are embedded. These continue for 1,000 miles or more northward along the eastern slopes. The nomenclature is open to objection; the rocks are rather rhyolites, andesites, etc.

In this Patagonian region the distinction between the coast, central, and east Cordillera is less clearly marked. Pre-Cordilleras or front ranges appear on the east side and are made up of granitic laccolithic intrusions. East of these, again, are found vast table-lands of basalt and other Tertiary effusives, which slope eastward and in places reach almost across Patagonia.

In southern Patagonia there is only one period of folding, involving Cretaceous and Tertiary beds, while farther north and indeed through the whole chain of the Andes there are two periods of folding, one Jurassic or older, the other late Mesozoic or early Tertiary.

ARGENTINA.

The recent work of Argentine geologists, such as R. Stappenbeck, H. Keidel, and others, has given us a clear idea of conditions along the eastern slope of the Andes. This is rarely a simple slope but usually a succession of ridges, the more easterly of which are called

[1] Geologisch-petrographische Studien in der Patagonischen Cordillera (Upsala, 1911).

[2] Practically all of the sediments of the region of Magellan Straits and Tierra del Fuego are considered as belonging to the Mesozoic series. On the west coast the batholithic rocks face the sea.

the pre-Cordilleras. In the extreme north, in Salta and Jujuy Provinces, really the continuation of the Bolivian Altiplanicie, the Paleozoic rests, according to Keidel,[1] with marked discordance on phyllites and quartzites of probably pre-Cambrian age.

In the eastern main Cordillera the marine Mesozoic (Jurassic and Cretaceous) rests unconformably on the basement of Paleozoic slates and includes great masses of flows of "quartz porphyries" and "melaphyres," i. e., rhyolites and basalts.

In the pre-Cordillera of San Juan and Mendoza[2] there are heavy continental deposits of upper Carboniferous to Upper Triassic age, resting on a Paleozoic folded basement. According to I. Bowman and other geologists these pre-Cordilleras continue northward into Bolivia and here also consist, in large part, of continental sandstone deposits. Small areas of porphyries and granite are intruded in these rocks. The series is gently folded toward the east.

On the eastern slopes of the Andes, sedimentary rocks generally predominate. Two periods of folding are recognized—an older Paleozoic and a younger Tertiary movement, the latter being designated as the properly Andene disturbances. Along the eastern border the latter is marked by overthrusts and overturned folds.

IV. DISTRIBUTION OF SOUTH AMERICAN DEPOSITS OF GOLD AND SILVER.

In the following paragraphs a brief summary is given of the distribution of the precious metal deposits in each of the cordilleran States of South America.

COLOMBIA.

In Colombia we find the principal gold belt of the Andes, which under adverse circumstances yields annually a notable production of $3,000,000 to $4,000,000. This production is probably capable of considerable expansion.[3] The total yield of that country, as calculated by Vincente Restrepo, amounts to about $700,000,000; therefore Colombia takes its place among the great gold-producing regions of the world.

The deposits are mainly in the western and central ranges, which do not continue northward into Panama, but bend eastward toward

[1] Ueber den Bau der Argentinischen Anden (Sitzungsberichte der Kaiserlichen-Königlichen Akademie der Wissenschaften (Wien, 1907). Pp. 649–674, Bd. CXVI, Abt. I.). Die neueren Ergebnisse der Staatlichen geologischen Untersuchungen in Argentinien (Compte Rendu, 11th session Congrès Géologique International, Stockholm, pp. 1127 to 1141 (1910).).

[2] R. Stappenbeck: La Pre-Cordillera de San Juan y Mendoza (Anales, Ministerio de Agricultura, Seccion geologica, Tomo iv. No. 3 (Buenos Aires).).

[3] The latest statistics for 1914 show a very marked increase in the production of Colombia, the figure being $4,676,600.

Venezuela. The eastern range, in which the city of Bogota is situated, appears to be lacking in precious metal deposits.

Heavy gravel deposits containing gold and platinum are found along the coast on the Atrato and San Juan Rivers, but the richest placers, some of which are now being dredged successfully, lie along the drainage trending northward, in the Magdalena, Porce, Cauca, and Nechi Rivers. These are deposits of great value though difficulties of transportation and climate have interfered with their successful exploitation.

The majority of the lode mines are in the departments of Antioquia, Cauca, Bolivar, Tolima, and Santander, of which the first two are the most important.

The deposits are mostly typical quartz veins, often with crystallized native gold, and more or less pyrite, pyrrhotite, arsenopyrite, chalcopyrite, galena, and blende, occasionally also tellurides. They are closely related to the California type and undoubtedly allied in their genesis to intrusive rocks. Though the deposits usually occur in granite and schists of probable pre-Cambrian age, porphyries or monzonites of much later date (probably early Tertiary) are usually found close to them. These intrusive rocks have sometimes been described as andesites or rhyolites.[1]

Among the deposits there is also another class, the representatives of which yield gold and silver or silver alone, and which occur in undoubted flow rocks, such as andesite and rhyolite. Many of them contain stibnite, tetrahedrite, pyrargyrite, jamesonite, and stephanite and were formed under materially different conditions and near the surface. Such mines are those at Marmato and Echandia in Cauca, and those near Manizales on the boundary of Tolima and Antioquia.

Altogether Colombia must be considered as the most promising gold-bearing region of South America.

ECUADOR.

Apparently Ecuador is not rich in deposits of precious metals. The coast is occupied by Cretaceous and Tertiary sediments, the former including some intrusive rocks. These are adjoined by a zone of igneous flow rocks of Tertiary or Recent age, surmounted by volcanic cones, while, according to W. A. Wolf, the best authority on the subject, the main or eastern cordillera is built of ancient schists and crystalline rocks.

Almost the whole of the moderate production of a few hundred thousand dollars comes from the ancient mines at Zaruma near the Peruvian boundary and 50 miles from the coast. According to J. R. Finlay, these veins are contained in a fine-grained diorite. In the

[1] H. W. Nichols and O. C. Farrington: The Ores of Colombia (Bulletin No. 38, Field Columbian Museum, 1899).

Esmeraldas near the coast and the Colombian boundary there are placer deposits which have not so far been successfully worked; the eastern ranges are also said to contain placers which may be derived from deposits of pre-Cambrian age.

PERU.

The conditions in Peru are very different from those in Colombia. There are relatively few gold deposits—some veins are being worked, and a certain amount of placer gold is obtained from the montaña region of southern Peru. The annual production of gold is rarely over $500,000; thanks to the careful work of the Cuerpo de Ingenieros de Minas it is possible to gain an exact idea as to its derivation. Half of the production comes from the copper of Cerro de Pasco. One-sixth is derived from placers and one-fourth from gold-quartz mines proper.

On the other hand, Peru is the leading silver-producing country in South America, the present annual output being about 9,600,000 ounces or 300,000 kilograms. Of this again more than one-half is derived from the copper mines of Cerro de Pasco, a small amount from lead bullion, and the remainder from silver or gold-silver deposits.

It is well known that Peru has yielded an enormous amount of silver. Professor Vogt has estimated 35,000,000 kilograms as the production from 1533 to 1910. Whether this is accurate or not, it is certain that Cerro de Pasco has contributed the greater part of the silver of Peru.

The silver districts are very numerous and generally situated in the western cordillera in the Departments of Cajamarca, Libertad, Ancachs, Huanuco, Juin (Cerro de Pasco), Lima, Huancavelica, and Arequipa. It would seem that the silver production could be considerably increased.

Geologically there is also a great difference from conditions in Colombia. In Peru and Chile we find along the coast and central Cordilleras a strong development of Jurassic and particularly Cretaceous sediments, folded and in part overturned toward the east. These Mesozoic sediments contain embedded lava flows of the same age, which, however, do not appear to be of importance as regards mineralization.

According to Prof. G. Steinmann,[1] the great majority of Peruvian deposits are undoubtedly in close genetic connection with numberless small intrusive masses of "andesite," "dacite," or "liparite." These names are confusing for the rocks are really deep-seated dioritic or

[1] Gebirgsbildung und Massengesteine in der Kordillere Südamerikas (Geologische Rundschau, Bd. 1, Heft 1–2 (1910)).

monzonitic porphyries not at all connected with the "effusives" or flow rocks.

It is thus clear that practically all of the Peruvian deposits are of the intermediate type, formed far below the surface. It is doubtful whether there are in Peru any deposits of the type of the Tonopah, Comstock, or Pachuca veins.

The great Cerro de Pasco deposits, for instance, occur in or close to a stock of "dacite" or "biotite andesite," which has metamorphosed the surrounding Cretaceous sediments. The proper name would seem to be biotite-diorite porphyry. In their upper levels the veins carried probably secondary silver ores of wonderful richness, while in depth they have been found to contain low-grade copper ores, which now form the basis of a great industrial enterprise.

Besides the smaller bodies of intrusive porphyries, there are also numerous large intrusive masses or "batholiths" of granodioritic rocks. Some of these form the central parts of the great ranges, and they may continue for a long distance with a width sometimes reaching 50 miles. Around these also there has been more or less mineralization, but of a more feeble character than attended the intrusion of the porphyries. The time of intrusion is taken to be early Tertiary.

In the gold-bearing region of southeastern Peru (northeast and north of Lake Titicaca) we find different conditions. Here the folded sedimentary rocks are of early Paleozoic age and more or less intruded by porphyries and granodiorites. This is in the regions of Carabaya and Sandia, and the Inambari Basin on the montaña slope. A very widespread, though not intense, mineralization has taken place; the primary gold deposits are apparently poor but the placers are widely distributed and numerous; partly successful attempts have been made to mine them. This belt is, in fact, the northern continuation of the great tin-silver-gold belt of the eastern range of Bolivia.

BOLIVIA.

Bolivia produces little gold at the present time, but its placers on the montaña side have at times yielded heavily. They lie on the eastern slope of the great range, east of Lake Titicaca, which counts among its peaks Sorata and Illimani, each over 21,000 feet in elevation. Celebrated among these were the placers of Tipuani on the east slopes of Sorata, which have yielded great amounts of gold since the time of the conquerors. There are many other localities south of this. Other placers have been worked recently on the San Juan River near the Argentine boundary. At the present time only two gold veins are worked, both in the eastern range and said to be of the

"saddle reef" type inclosed in slates and sandstones.[1] The quartz and free gold are accompanied by pyrrhotite, arsenopyrite, and pyrite. They thus belong to the intermediate type accompanying intrusive rocks. The ore is of low grade.

Bolivia points with pride to its production of silver. The yield from 1553 to 1910 is stated to have been 48,800,000 kilograms, to which the mines of Potosi are said to have contributed no less than 30,000,000 kilograms, making this district the greatest silver mine the world has known. Nor is this large production entirely a matter of the distant past, for it is said that the Compagnie de Huanchaca de Bolivia sent to the markets of the world from its mines, which lie to the south of Potosi, silver and lead to the value of $50,000,000 between the years 1873 and 1888. At present Bolivia yields 80,000 to 150,000 kilograms (2,500,000 to 4,800,000 fine ounces) per annum. A large part of this comes as a by-product from the tin mines; another part is derived from the mines near Huanchaca.

The great mineral belt of Bolivia lies in the extremely rough chain which forms the eastern border of the Altiplanicie or high plateaus of that country, a region of Paleozoic folded slates with intrusive cores of diorite, granite, and porphyritic intrusions. Volcanoes and lava flows are generally absent. In this range there has been produced a widespread mineralization, in part of gold but more characteristically of the peculiar type of Bolivian tin veins first described by Stelzner, and carrying both silver and tin. All these deposits extending from the Peruvian boundary almost to the Argentina border are certainly of the deep-seated type connected with intrusive rocks. In general, these are porphyritic, and may be designated as quartz porphyry or granitic porphyry. In the literature they are frequently referred to as andesite and rhyolite, which usage tends to produce an erroneous impression. There are probably no deposits in Bolivia of the type formed near the surface in flow rocks.

Interesting changes are observed in depth. Just as the Cerro de Pasco silver veins turned into low-grade copper veins in depth, so the wonderfully rich silver veins of Potosi are shown, as the great mountain is penetrated by deep adits, to have been transformed into pyritic tin-bearing veins. The silver production from this district is now of smaller moment than formerly.

CHILE.

Lack of data makes it difficult to review at a distance the deposits of Chile. The Republic of Chile, so progressive in other

[1] F. C. Lincoln: Incaoro Mine (Mining and Scientific Press, vol. cviii, No. 14, p. 561 (Apr. 4, 1914)).

respects, has made little effort to study or keep account of its mineral deposits.

The narrow strip of coast occupied by the Republic is in few places more than 150 miles wide, but extends from the eighteenth to the fifty-sixth degrees of south latitude. From latitude 20° to 36°, a distance of 1,200 miles, this part of the Pacific slope is mineralized in a complex and manifold way, while the remaining distance to Cape Horn contains extremely few gold and silver deposits. This is surely a remarkable feature.

It is not my purpose to describe the great resources in copper which have lately been developed in Chile; these deposits as a rule contain little or nothing of the precious metals. Chile has never yielded very large amounts of gold. At the present time the production appears to be diminishing, as may be seen from the following table, and does not exceed a few hundred thousand dollars per annum. The silver production is a little more valuable, but scarcely reaches 30,000 kilograms (900,000 ounces) per annum. At no time has the silver reached the figures of Bolivia and Peru, although the rich deposits of the northern coast during a short period in the nineteenth century made Chile prominent among silver-producing countries.

The present moribund condition of the industry certainly appears strange when we consider the almost continuous chain of mining districts extending over a distance of 1,200 miles.

The total gold production of Chile from the sixteenth century up to 1900 is estimated by Herrman[1] at $212,000,000, or less than a third of that of Colombia.

The total production of silver is estimated at 6,000,000 kilograms, only a small part, it will be observed, of the yield of Peru and Bolivia.

The northern half of Chile shows in general a geological structure similar to that of the western cordillera of Peru. The Jurassic and Cretaceous formations are strongly developed with contemporaneous lava flows of great volume. Into these are intruded granite porphyries and diorite porphyries in smaller stocks, as well as many batholithic masses of granodioritic rocks. Both of these kinds of intrusions have brought mineral deposits. There are finally heavy masses of late Tertiary lava flows, and in these we find a few representatives of the type of precious metal veins which were formed near the surface. The great majority of deposits are associated with intrusive rocks and many of these carry tourmaline with copper and gold, indicating that they were formed under conditions of high temperature. It is necessary to read the descriptions critically, for

[1] La Produccion en Chile de los Metales y Minerales. Santiago de Chile (1903). See also Malcolm Maclaren (Gold, p. 662 (London, 1908)).

here, as elsewhere in South American literature, andesite, dacite, and rhyolite are names often used for intrusive Tertiary rocks, a survival of the old view that any Tertiary volcanic rock must belong to one of these rock types.

Some gold-bearing veins are found in rhyolite and allied flow rocks, for instance, at Guanaco, southeast of Antofagasta, probably also at Sierra Overa, southeast of Taltal, and at Andacollo, southwest of Coquimbo. Other veins carrying both silver and gold occur, according to Moericke,[1] in andesite flows, in part tuffaceous, for instance, at Batuco and Cerro Blanco. According to Moericke all veins of this type seem to have a tendency to play out at a depth of a few hundred feet.

Much more numerous are the gold quartz veins connected with intrusives, such as granites and quartz diorites. We find them at Capotillo,[2] north of Taltal, in diorite intrusive in Cretaceous limestone. Others are found associated with tourmaline and copper ores at Remolinos in Atacama, at Tamaya and La Higuera in Coquimbo, and at Las Condes in Santiago. Another gold belt extends from Coquimbo down to Santiago, and to Rancagua and Talca, south of this city.[3] These quartz veins occur mostly in granite near the contact of schist.

While silver is sometimes associated with gold, the richest silver mines of Chile, which yielded great amounts of the metal in the nineteenth century, occur as a rule separate in Mesozoic limestone, intruded by or interbedded with greenstones of various kinds. They are characterized by extremely rich ore and antimonial and arsenical silver minerals; some of them also contain silver amalgam. Their genesis is doubtful. The gangue is mainly calcite. In depth these veins also are disappointing and the silver production of Chile is now only a fraction of what it was when these mines were in bonanza.

Among these celebrated districts, mainly situated along the coast, are Huantajaya and Challacollo near Iquique, Chañarcillo (50 miles south of Copiapo), and finally a group of districts including Arqueros and Condoriaco (100 miles south of Copiapo).

The great low-grade copper deposits, such as Braden and Chuquicamata, appear to contain very little of the precious metals.

In remarkable contrast to the northern half, so rich in precious metal deposits, the southern part of the Republic appears to be amazingly poor in mineral deposits. Scarcely any mines are re-

[1] W. Moericke: Einige Beobachtungen ueber Chilenische Erzlagerstätten (Tschermak's Min. u. Pet. Mitteilungen, vol. xii, pp. 186 to 194 (1891)).

[2] S. H. Loram: Notes on the Gold District of Capotillo, Chile (Trans., vol. xxxv, p. 866 (1905)).

[3] E. D. Pope: Gold Mining in Chile (The Mining Magazine (London), vol. xiii, No. 1, pp. 33 to 36 (July, 1915)).

ported from this region except an auriferous vein worked by the Spaniards near Valdivia, and some auriferous beach sands along the coast, for instance, on Chiloe Island. Not until we reach the Straits of Magellan are there any producing deposits. At Punta Arenas on these straits and on the eastern side of the Andes there are gold-bearing gravels rich enough to justify dredging. Similar placers are found on the south side of the straits in Tierra del Fuego. About 1902 a dozen dredges were erected here and for a number of years these gravels have contributed largely to the gold production of Chile, yielding annually up to $100,000. The production has decreased materially during the last few years, owing, it is said, to difficulties in dredging the bowldery deposits.

The difference in mineralization is intimately connected with a great change in topographical and geological conditions.[1] From latitude 42° down to Cape Horn the cordillera is invaded by the ocean and by ice. Its westerly margin is cut up into an intricate system of fjords, and its summits are clad in the armor of immense ice fields. A huge batholith of granitic and dioritic rocks occupies the whole western range, probably from Puerto Montt to the tip of the continent. This constitutes a striking analogue to the batholith of British Columbia; it is of greater length and its width in many places reaches 100 kilometers. On the east side the ice fields often cover its margins. On the west side the adjoining sedimentary rocks are largely submerged, but on Wellington and Chiloe Islands these western sedimentaries begin to appear as metamorphosed schists of uncertain age. All along the eastern side the batholith is intruded in Mesozoic (Cretaceous and Jurassic) rocks. Along the eastern edge of the latter we find again front ranges of granitic laccoliths, such as Cerro Payne, Cerro Balmaceda, etc., most of them consisting of granitic rocks. There is little doubt that the gold placers of Punta Arenas have derived their metal from the mineralization along the eastern side of the great Chilean batholith. It would be strange if this batholith would not be accompanied by mineral deposits. That no such have been found may in part be accounted for by the extensive present and former glaciation which would destroy most placer deposits and to the fact that the region is extremely inhospitable. It would not be surprising if scientific prospecting along the borders of this batholith should lead to the discovery of gold-bearing deposits.

ARGENTINA.

The present Argentine production of gold and silver is very small indeed, and the country has never yielded large amounts of these metals.

[1] P. D. Quensel: Geologisch-petrographische Studien in der Patagonischen Cordillera (Upsala, 1911).

The sierras of the pampas, like that extending from San Luis to Cordova, contain a feeble pre-Cambrian or early Cambrian mineralization, referred to above, but these quartz veins appear to be poor in gold and silver. In the same vicinity there is also evidence of a much later development of gold deposits, perhaps connected with the effusion of Tertiary andesitic lavas, but these veins which have the character of crushed or sheeted zones are also poor in gold.[1]

The whole eastern slope of the Andes from the Bolivian plateau to the latitude of Santiago de Chile shows a relatively feeble mineralization. The slopes of the central cordillera and the pre-Cordilleras are largely composed of sedimentary rocks folded, overturned, and overthrusted toward the east, with relatively small and inconspicuous areas of igneous rocks,[2] which are designated as andesites and dacites, but which in reality seem to be holocrystalline intrusives. There are also smaller areas of granular rocks of Tertiary age, which were designated as "Anden diorite" by Stelzner.

Gold, silver, and copper prospects are rather abundant, but at very few places has serious work been undertaken. The most important deposit, located at Famatina, is a copper-bearing vein with sulpharsenides and antimonides of copper and very little gold and silver.

The eastern slope of the Andes in the northern half of the Argentine Republic is comparable in a way to the eastern Rocky Mountain chain of Canada. Both show overturned folds and overthrusts toward the east, with comparatively little of intrusive rocks and attendant mineralization. The gold-silver-tin belt of the Bolivian eastern cordillera apparently does not enter the Argentine territory.

No lode deposits are reported south of Mendoza, except on the headwaters of Neuquen River, at about the latitude of Concepcion in Chile, where there is a mining district of gold-bearing quartz veins in granite of uncertain age. Considerable work has been done on these, but the expected production does not seem to have been realized. The ore is apparently of low grade. The only other precious metal deposits reported from the eastern slope of the Andes in Patagonia are placers of doubtful value on the headwaters of Chubut, Rio Gallegos, and other streams. Placers and some lode mines have been taken up at various places on the Argentine Tierra del Fuego, but little information is available as to their values.

As observed above, the Mesozoic beds of the Patagonian cordillera and eastern cordillera are intruded by laccolithic and batholithic masses of granitic rocks, and careful prospecting might well yield

[1] E. Gerth: Constitucion geologica de la Provincia de San Luis (Anales Ministerio de Agricultura, Seccion Geologica, Tomo x, No. 2, 1914).

[2] R. Stappenbeck: La Pre-Cordillera de San Juan y Mendoza (ibid., Tomo iv, No. 3).

favorable results. The glaciation probably would have destroyed any placers which may have existed in this region, and this guide for the prospector is, therefore, generally lacking.

V. COMPARISON OF THE TWO CONTINENTS.

It has been shown that the pre-Cambrian and early Paleozoic gold deposits predominate in the eastern part of North and South America; that they are scattered irregularly over a wide territory and do not form well-defined belts except locally; and that the heavy production is very much localized. There is reason to believe that such deposits occur here and there in the pre-Cambrian rocks of the cordilleran regions, though they are not easily differentiated from the later cordilleran period of mineralization. We note the marked localization of rich deposits in the Black Hills and in the Porcupine, which may be compared to the strongly auriferous districts of the Guianas and Minas Geraes. We observe, also, that as far as this earliest mineralization is concerned, both continents are about equally rich. No silver deposits of this period, such as are concentrated to such a remarkable degree at Cobalt, Ontario, are known from South America.

In the cordilleran region of South America the principal and almost the only period of mineralization seems to be that of the early Tertiary, while in North America an important series of deposits dates from the early Cretaceous. The batholithic and smaller intrusions in South America all appear to date from early Tertiary, and the evidence of close connection between intrusion and mineralization is cumulatively strong and convincing. The same general principles of association of the two agencies apply in the two continents.

So far, no definite evidence has been adduced that the great lava flows of the Jurassic and Cretaceous contain mineral deposits of that general age. In North America many intrusions—in fact the greatest batholiths—date from the earliest Cretaceous. No such occurrences are found in South America.

From northern Mexico to Chile the Cretaceous is by far the most prominent of the sedimentary formations, while the Carboniferous limestone, so important for the mineralization of the Cordilleras in the United States, is entirely lacking.

Another interesting feature is the great scarcity in South America of Tertiary deposits of gold and silver occurring in late Tertiary lavas and formed close to the surface. Popularly the majority of deposits in South America are ascribed to this group, and even the latest textbooks fall into this error. There are some of these interesting and rich deposits in the southern Provinces of Colombia, but none have been recorded in Peru and Bolivia. In Chile they re-

appear at some places such as Guanaco, Batuco, and Cerro Blanco, but compared to the deposits of other classes they are rare. This is remarkable, when we consider the widespread occurrence in Central America, Mexico, and the western United States of deposits of the type of Pachuca, Guanajuato, the Comstock, and Tonopah, all marked by certain well-defined characteristics.

A large number of deposits in Colombia, Bolivia, and Chile approach the high-temperature veins by their content of pyrrhotite and tourmaline.

A curious fact is that, so far, no contact-metamorphic deposits are described from Peru and Chile, although metamorphism of the Cretaceous limestone by the granodioritic intrusions is often mentioned. In the Cordillera Real of Bolivia they would hardly be expected, for there the intruded rock is generally a slate or sandstone.

The poverty of the eastern front ranges of the Andes is paralleled by the lack of precious metal deposits in the eastern or Rocky Mountain Range of Canada.

North America stands out in its richness of placer deposits derived from veins of the Cretaceous intrusive period. In South America there is no real counterpart to the great placers of California, Idaho, Montana, Alaska, and Yukon Territory.

The placer deposits of the Andes, which were locally rich, were mostly found on the eastern slopes of the eastern ranges, and were derived from gold-bearing veins in Paleozoic slates, with intruded granite porphyries and allied rocks.

Colombia stands out prominently as the most valuable gold-bearing region of the Andes, from which, in spite of many difficulties, we may expect a considerably increased production.

The next region is formed by Peru and northern Chile—a region of very numerous mining districts in which the mineralization is chiefly in the direction of silver and copper with a few gold-bearing localities, which, however, do not seem to be able to achieve great production. No doubt the silver output could be materially increased, particularly where silver occurs with copper. In looking over the numerous gold-bearing districts of central Chile the student would like to ascertain the conditions which in so favored a country have held back the production to such a marked degree.

The third region is formed by the Cordillera Real of Bolivia, with its rich mineralization of tin, silver, and (subordinately) gold. Undoubtedly this region is one of the most promising in South America.

Lastly, a striking contrast is presented between the two tips of the cordilleran chain. At the north is Alaska, rich in gold, at the south is the Patagonian cordillera, with its gigantic batholith, so promising theoretically, so barren in reality. It is barely possible that theory

may be vindicated and that valuable deposits may be found hereafter in this vicinity.

It is difficult to avoid the conclusion that the South American Andes are somewhat less intensely mineralized in precious metals than the corresponding chain in the northern continent, and that even progress and enterprise will be unable to raise its production of gold and silver to approach the figures attained by North America.

APPENDIX.

Production of gold and silver in the American Continent for 1913.

(From the reports of the Director of the Mint and from tables in Mineral Industry.)

[Value of 1 kilogram: Gold, $664.60; silver, $19.]

	Gold.		Silver.	
	Kilograms.	Value.	Kilograms.	Value.
South America:				
Venezuela	....	$411,300	....	....
British Guiana	2,006	1,333,300	....	....
Dutch Guiana	706	470,400	....	....
French Guiana	4,600	3,058,500	....	....
Brazil	3,372	2,234,700	....	....
Uruguay	120	79,800	....	....
Colombia	4,471	2,971,700	42,300	$560,000
Ecuador	613	406,500	....	....
Peru	741	492,500	296,132	5,643,600
Bolivia	[1] 140	93,000	81,300	1,544,700
Chile	[1] 1,000	664,600	[2] 30,178	573,400
Argentina	[1] 4	2,600	1,062	20,200
Total	17,714	12,166,200	451,807	8,603,400
Central America	4,095	2,721,700	[1] 68,427	1,300,100
North America:				
Canada	24,976	16,598,900	990,000	15,944,000
United States	133,741	88,884,400	2,074,700	40,348,100
Mexico	28,900	19,206,500	[5] 2,112,600	40,144,300
Total	187,050	124,792,100	5,177,000	96,476,400
Grand total	209,425	139,683,000	5,697,334	106,380,900

[1] Estimated; no exact figures available.
[2] Figures of 1912.
[3] Probably too low.
[4] For 1912. See Report of Director of the Mint for calendar year 1913, p. 267.
[5] Fiscal year 1912-13.

Average production of gold in the American Continent for the years 1908–1912.

(From the Reports of the Director of the Mint and from the tables in Mineral Industry.)

South America:		
Venezuela	$245,300	
British Guiana	1,338,820	
Dutch Guiana	578,650	
French Guiana	2,177,640	
Brazil	2,400,150	
Uruguay	90,650	
Colombia	2,884,500	
Ecuador	271,430	
Peru	625,080	
Bolivia and Chile	612,770	
Argentina	107,380	
		$11,809,360
Central America		2,585,090
North America:		
Canada	12,170,510	
United States	90,780,000	
Mexico	19,711,050	
		122,670,020
Grand total		136,583,600

THE COMPOSITION AND STRUCTURE OF METEORITES COMPARED WITH THAT OF TERRESTRIAL ROCKS.[1]

By George P. Merrill,
Head Curator of Geology, U. S. National Museum.

(With 9 plates.)

The name "meteorite" is applied to masses of stone and iron which occasionally find their way to the earth from space. They are the tangible evidences of the identity of matter in the meteor or shooting star with that of our sphere. Their fall, if such it can properly be called, is accompanied by a rush and roar like that attendant upon the swift flight of any solid body through the atmosphere. Almost invariably, also, there is an explosion or series of explosions giving rise to sounds comparable to the firing of musketry or heavy cannonading. Falls occurring after sundown are usually accompanied by a trail of light which is due to combustion caused by the pressure of the atmosphere. Few accurate illustrations of falls are available, since the brief time occupied by the phenomenon gives little opportunity for photograph or sketch and too much is left to the imagination to make them of value. Those here given (pl. 1) are of falls which took place near Quenggouk in India in 1857 and in Kayahinya in 1866. The meteorite as found, if a stone, presents almost invariably a thin, glassy, dark colored crust, which is due to the fusion of the meteorite on its outer surface and the rapid cooling which ensues on its reaching the ground. In many instances, it is beautifully fluted by this stripping off of the fused material in its flight through the atmosphere, as shown in the stone which fell near Bath Furnace, Kentucky, 1902 (fig. 1).

Fig. 1.—Stone meteorite, Bath Furnace, Ky.

Although it is estimated that thousands and even millions of these bodies come into our atmosphere every day, but few of them reach

[1] Adapted from a lecture delivered before the Geological Society of Washington.

the earth in recognizable form, being entirely consumed, while of those that do survive but a comparatively small number are ever found. Ward, in his summary of 1904, gave the number of distinct falls and finds recorded, and of which specimens have actually been held in human hands, as 815. The total weight of meteoric matter annually added to our earth, a considerable part of it probably as mere meteoric dust, has been estimated at 100,000 tons.

Meteorites, as they come to us, are unquestionably fragments. In many instances, perhaps in most instances, their final breaking up took place after entering our atmosphere, and to this is due the explosion which is an almost invariable accompaniment of a meteoric fall. The smallest recorded meteorite constituting an entire fall is that of Mühlau in Austria, which weighed 5 grams; the largest is the monster iron brought by Commander Peary from Cape York, Greenland, in 1897 and which weighed some 37½ tons. Second only to this is the so-called Bacubirito iron, a large, scalelike mass lying in Sinaloa, western Mexico, which may perhaps weigh 15 to 20 tons. Both of these, it will be noted, are irons. The largest known individual meteoric stone is that of Knyahinya, Hungary, which weighed 293.5 kilos or 645 pounds.

All meteorites thus far found are unquestionably of igneous origin. It is customary to divide them upon lithological grounds into three classes which merge into one another, however, by all gradations. These are: (1) Those of an almost purely metallic nature, composed mainly of nickel-iron with nickel and iron phosphides and sulphides which are known as siderites. The Casas Grandes iron, weighing some 3,407 pounds (pl. 2) is a good example of this type. (2) Those consisting of a spongy mass of iron inclosing silicate minerals and known as stony irons, siderolites, or pallasites, like that of Mount Vernon, Kentucky (pl. 3). (3) Those which are essentially stony throughout and known as meteoric stones or aerolites of which that of Modoc, Kansas (fig. 1, pl. 4), is a good illustration. These classes I will consider in the order given, but will first refer briefly to the kinds of elementary matter the meteorites contain and their form of chemical combination.

Out of the more than 40 elements that have been reported as found in meteorites, the presence of the following, named in alphabetical order, may be considered as fairly well established: Aluminum, argon, calcium, carbon, chlorine, chromium, cobalt, copper, helium, hydrogen, iridium, iron, magnesium, manganese, nickel, nitrogen, oxygen, palladium, phosphorus, platinum, potassium, radium, ruthenium, silicon, sodium, sulphur, titanium, and vanadium. These are all constitutents of our own sphere also, though their mode of combination is in some cases radically different. In the list given below, the minerals of meteorites are divided into essential and acces-

1. SKETCH OF FALLING METEORITE AT QUENGGOUK, INDIA, IN 1857.

Sitzungsbericht der K. Akad. der Wiss. 1862.

2. SKETCH OF FALLING METEORITE AT KNYAHINYA, HUNGARY, IN 1866.

Sitzungsbericht der K. Akad. der Wiss. 1866.

FIG. 1.—MASS OF METEORIC IRON, CASAS GRANDES, MEXICO.

FIG. 2—ETCHED SLICE OF SAME SHOWING WIDMANSTÄTTEN FIGURES AND TROILITE NODULES.

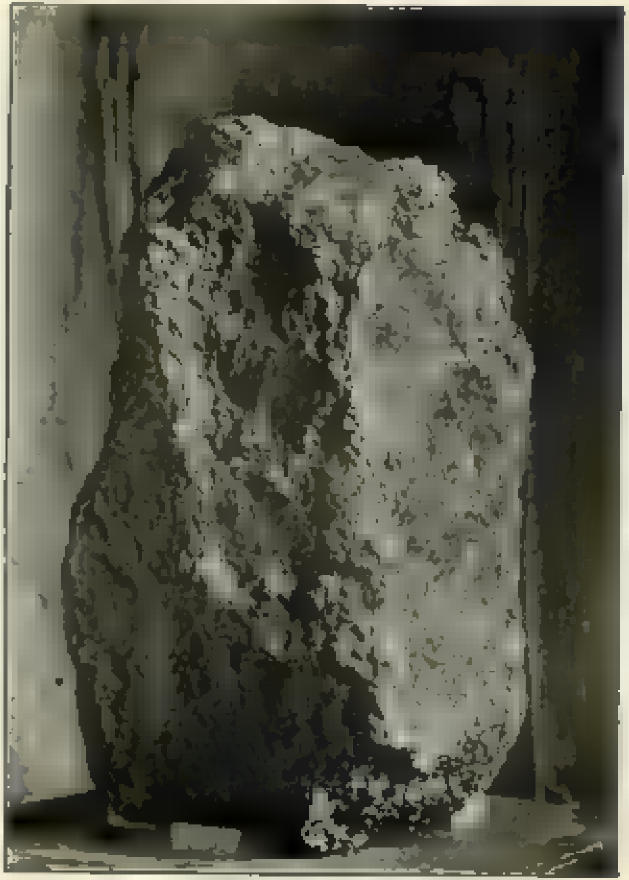


FIG. 1.—PALLASITE, MOUNT VERNON, KY.

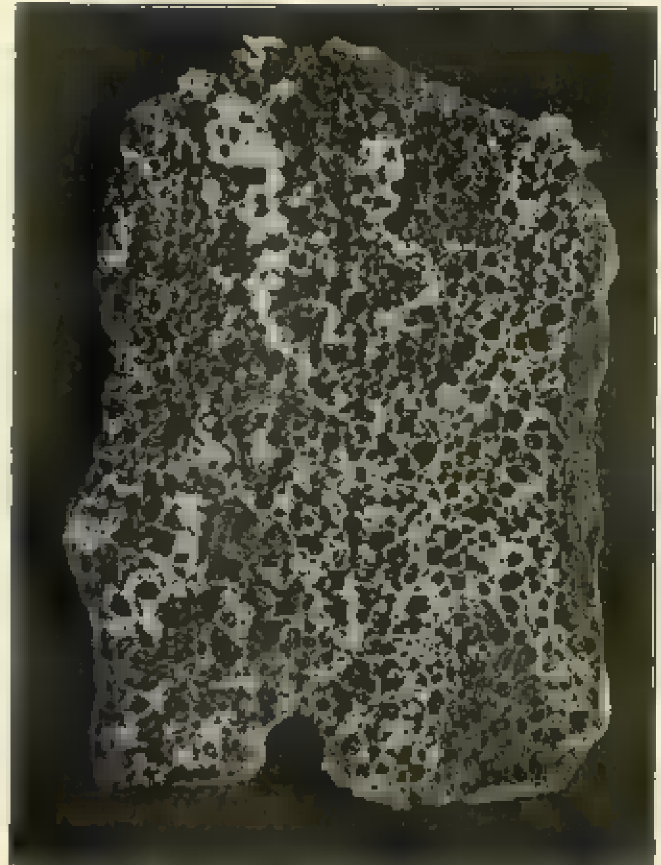


FIG. 2.—POLISHED SLICE OF SAME SHOWING OLIVINES (DARK) IN A NETWORK OF METALLIC IRON.

FIG. 1.—STONY METEORITE, MODOC, KANS.

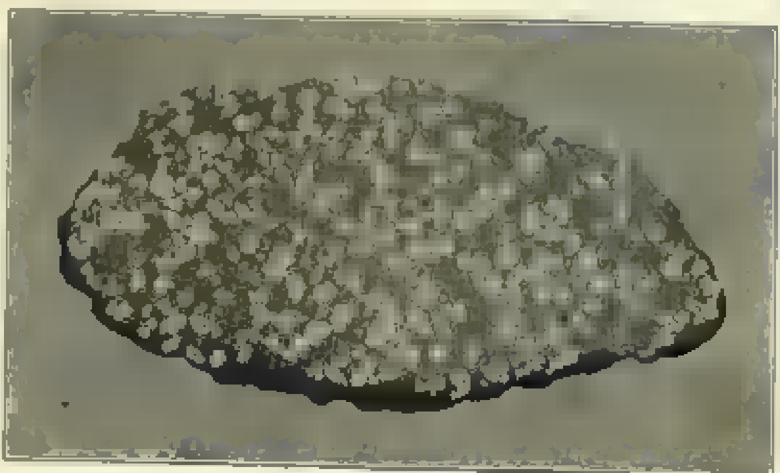


FIG. 2.—POLISHED SLICE OF BASALT SHOWING METALLIC GRANULES IN SILICATE BASE.

sory, including under the first term those constituting any essential part and the presence or absence of which affects them fundamentally; while the accessory minerals include those occurring in smaller and usually inconsequential quantities. The essential minerals then are: Nickel-iron, olivine, orthorhombic and monoclinic pyroxenes, plagioclase feldspar, maskelynite, and iron sulphides. The accessories are: Carbon, either amorphous or as graphite and the diamond; chromite, cohenite, daubreelite; the gases carbon monoxide and dioxide, hydrogen and nitrogen; lawrencite, magnetite, oldhamite, osbornite, schreibersite, a calcium phosphate to which the name of merrillite has been given, and tridymite. In addition there is occasionally a small amount of undifferentiated glass. Concerning these minerals a few explanatory remarks seem necessary, since several of the compounds are little or quite unknown among terrestrial rocks.

The metallic iron of meteorites invariably carries nickel and cobalt in amounts varying from 4 to 20 per cent of the former and 0.5 to 2 per cent of the latter. The nearest approach to this composition in terrestrial irons is found in the awaruite of New Zealand, which contains 67.63 per cent of nickel and 31.02 per cent of iron, and josephinite of Oregon which carries theoretically 72.42 per cent of nickel and 27.58 per cent of iron. The Ovifak, Greenland, iron, a constituent of basalt, carries at the maximum only between 6 and 7 per cent nickel. Perhaps the most interesting feature on the part of most meteoric irons is an apparent tendency to separate on crystallizing into alloys of more or less definite composition which owing to their varying solubility give rise to well-defined and characteristic markings known as Widmanstätten figures when a polished surface is treated with dilute acid. These alloys were studied by Reichenbach in 1861, who gave to them the name *balkeneisen* or kamacite, *bandeisen* or taenite and *fülleisen* or plessite, the last named being probably a mixture of the other two. The following analyses of kamacite and taenite from the iron of Welland, Canada, were made by Prof. Davison, of Rochester:

Constituents.	Kamacite.	Taenite.
	Per cent.	Per cent.
Iron	93.09	74.78
Nickel	6.69	23.32
Cobalt	.25	.80
Carbon	.02	.50
	100.05	99.40

It should be stated, however, that analyses made by various workers are found not to agree at all closely, a fact doubtless due in large part to the difficulty of separating them perfectly one from another. The etched slice of the Casas Grandes iron on plate 2, fig. 2

well shows the characteristic Widmanstätten figures on an octahedral iron of medium texture. The smaller, more highly magnified section here reproduced (fig. 2) shows more plainly the portions to which the various names are given.

FIG. 2.—MAGNIFIED SECTION OF WIDMANSTÄTTEN FIGURES ON CASAS GRANDES IRON.

It has been shown by Berwerth, of Vienna, and some corroborative tests made in the laboratory of the National Museum, that the octahedral structure can be changed by heating for a more or less prolonged period at temperatures far below that of fusion, and it seems not improbable that the granular structure characteristic of irons of the ataxite group may, in some cases at least, be of a secondary nature. It is evident that the full significance of the crystallization of meteoric irons is to be learned only by synthetic studies such as it is to be hoped may be undertaken in the laboratories of some of our more modern institutions.

Associated with the nickel-iron is almost invariably an iron-nickel phosphide of a somewhat variable formula named "schreibersite" by Haidinger in 1847. A dendritic form of this occurring in the Arispe, Mexico, iron is shown in figure 3. Sulphide of iron, often in the form of rounded nodules, is also a common constituent as shown in the etched section of the Casas Grandes iron (fig. 2, pl. 2). This appears to be a monosulphide and was named "troilite" by Haidinger. Meunier, however, thinks to have shown it to be pyrrhotite. As the mineral is without crystalline form and rarely pure, there is room for doubt in the matter.

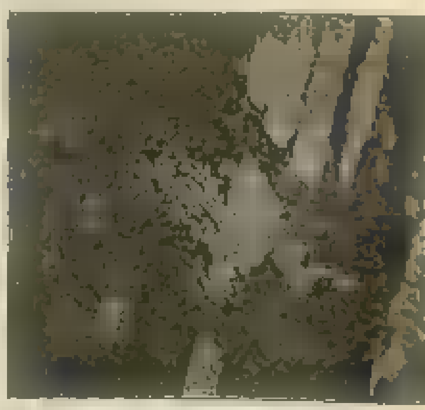


FIG. 3.—ARISPE, MEXICO, IRON, SHOWING SCHREIBERSITE.

Carbon is a common constituent. The appearance of a cubic form of graphite in the Magura iron was noted by Haidinger in 1846. Such forms were suggested by Rose to be pseudomorphs after the diamond, but no satisfactory evidence was offered in proof. In 1888 Messrs. Jerofeieff and Latschinoff, in studying the carbonaceous meteorite of Novo-Urei, Russia, found a graphitic mineral having

the hardness and shape of the diamond. In 1889 E. Weinschenk separated from the Magura iron a minute quantity of transparent crystals which were hard enough to scratch ruby, and burned in oxygen, forming carbonic acid. In 1891 A. E. Foote, in cutting the Canyon Diablo meteoric iron, found a black, vitreous mineral having a hardness above that of sapphire, and which he announced to be diamond. Later, O. W. Huntington, by dissolving a considerable quantity of this iron, was able to isolate a considerable number of minute, colorless particles which had not merely the hardness of diamonds, but the crystal outlines as well. The crystals found by Huntington were, it should be stated, minute—but about a hundredth of an inch in diameter. Since Huntington's work, diamonds have been separated from the Canyon Diablo and other irons by several workers.

Under the name of Cliftonite, Fletcher in 1887 described a form of carbon occurring in minute cubical crystals with dodecahedral and tetra-kis-hexahedral modifications which he found in the iron meteorite of Youndegin, West Australia. The crystals were of pure carbon, easily frangible, with a hardness of 2.5 and specific gravity of 2.12. After a full consideration of their crystalline form and physical condition with especial reference to their possible pseudomorphous nature, Fletcher concluded that they represented "an allotropic condition of crystallized carbon distinct from both diamond and graphite," and gave the name, as above.

Carbon in the form of graphite, both crystalline and amorphous, is a common constituent of meteorites, particularly the iron-rich varieties, where it occurs in disseminated scales and nodular masses often of considerable size. The percentage amount by weight is always small owing to the relative lightness of the carbon, but in the Novo-Urei, Orvinio, and some other stones, it is sufficiently abundant to impart to them a decided dark gray to nearly black color. The Novo-Urei stone was estimated to contain some 1.26 per cent of amorphous carbon, and 1 per cent in the form of diamond.

Cohenite is the name given to a carbide containing some 90 per cent of iron, 3.5 per cent of nickel and cobalt, and 6.5 per cent of carbon. Daubreelite is a sulphide of iron and chromite of the formula, FeS, CrS_3, which was isolated, analyzed, and named by J. Lawrence Smith in 1876. Lawrencite is a green, semisolid ferrous chloride almost invariably present in meteorites, but which undergoes such ready oxidation as to shortly disappear on the immediate surface. The mineral is a sore trial to all keepers of meteorite collections. Oldhamite is the name given by Maskelyne in 1862 to a calcium sulphide found in the meteorite of Busti, India. It occurs in microscopic proportions in rounded granular forms of a chestnut brown color. Under atmospheric influences it passes by oxidation into gypsum. The same investigator gave the name "osbornite" to

a mineral occurring in small, golden yellow octahedra in this same meteorite, and judged from partial analysis to be an oxysulphide of calcium and titanium. Free silica in meteorites is extremely rare. Maskelyne described what he considered a rhombic form of quartz as constituting nearly one-third of the siliceous portion of the Breitenbach pallasite. The association of free silica in such proportions with olivine and native iron is quite unusual.

From what is known regarding terrestrial basic igneous rocks, the feldspars of meteorites would naturally be assumed to belong to the more basic varieties, as labradorite and anorthite. Few actual and complete analyses are available owing to the difficulty of securing a sufficient quantity of material in a fair degree of purity. Those given below from the meteorites of Hvittis, Hessle, and Shergotty show that in at least two instances the feldspar is approximately oligoclase, a form characteristic of rocks of intermediate acidity, as the diorites. The third analysis represents a completely isotropic, colorless mineral forming, together with augite, the essential constituents of the meteorite of Shergotty, and which is regarded by Tschermak, who described it in 1872, as a re-fused feldspar, near labradorite in composition. To this he gave the name "maskelynite." It should be stated that Groth was inclined to regard it as an independent species and allied to leucite.

Constituents.	Sources.		
	Hvittis.	Hessle.	Shergotty.
Silica	63.5	64.07	56.3
Alumina	21.3	22.06	25.7
Lime	4.0	3.01	11.6
Soda	9.2	9.06	5.1
Potash	1.1	...	1.3
	100.00	100.00	100.00

The feldspars, it may be said as a general statement, are not prominent constituents of meteorites and are limited mainly to those of a basaltic type. In these they occur in the characteristic, lath-shaped forms, polysynthetically twinned. In the chondritic types they occur in the form of sporadic granules, sometimes showing twin striæ, and in the nearly isotropic maskelynite forms occupying the interspaces of other silicates. Concerning the other silicates present, it may be said that the olivines, excepting in the barred chrondritic forms, apparently differ in no essential particulars from those of terrestrial rocks. The pyroxenes, however, show interesting peculiarities. We find, as among terrestrial rocks, both orthorhombic and monoclinic forms, but the first named are the more common. These occur in colorless to grayish—rarely greenish—forms, and in

several of the known instances prevail to the almost entire exclusion of other constituents. The more common varieties, as will be noted from the accompanying table, are enstatite and bronzite, though hypersthene has been reported in the stone from Shalka. The mineral, however, is not as pleochroic as is its terrestrial counterpart. Many of these have been identified crystallographically, and agree in form and faces with those of terrestrial rock, although the crystal outlines and cleavages are, as a rule, very poorly developed.

Analyses of meteoric orthorhombic pyroxenes.

Locality.	SiO_2.	MgO.	FeO.	Na_2O.	K_2O.	CaO.	Al_2O_3.
Bishopville	59.97	39.34	0.40				
Busti	55.44	38.34	1.14	0.36	0.33	1.68	
Lodhran	55.55	27.65	12.13			.64	0.90
Breitenbach	56.05	30.66	12.44				
Hainholz	53.08	23.40	15.63			2.71	3.19
Ibbenbühren	60.05	37.10	.60	.06	.47	.98	1.09
Goalpara	60.03	28.00				2.11	
Molina	57.6	39.32	.91				2.07
Shalka	53.65	27.70	18.53	.92		.09	
Rittersgrün	57.49	33.79	10.58	1.45		2.12	2.09

In addition to these terrestrial forms there are others radically different. Especially characteristic are eccentric and radiated forms some of which are shown in the photomicrographs (pls. 8 and 9).

The monoclinic pyroxenes are less abundant than the orthorhombic, and but for inclined extinctions of clinopinacoidal sections are often difficult to distinguish. The most striking peculiarity of this form is a decided tendency to polysynthetic twinning. This manifests itself in fine, parallel striations traversing the section and has caused the mineral on casual inspection to be mistaken for a plagioclase feldspar. Most of the analyses given in the literature are of materials separated from other constituents by the use of acids, but I have here limited myself to two analyses of such as have been separated mechanically.

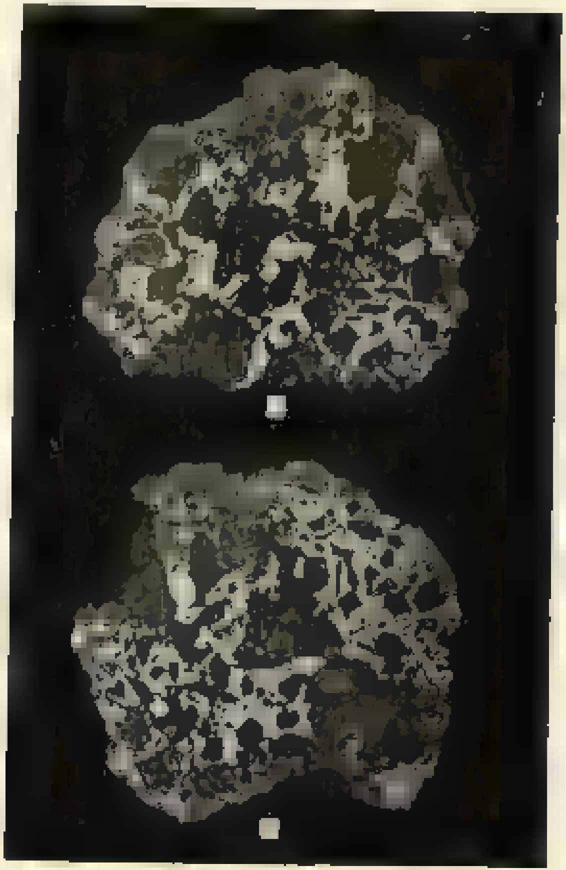
Constituents.	Source.	
	I. Busti.	II. Shergotty.
Silica (SiO_2)	55.49	52.34
Alumina (Al_2O_3)		.25
Ferric oxide (Fe_2O_3)	.60	
Ferrous oxide (FeO)		21.19
Magnesia (MgO)	22.53	14.29
Lime (CaO)	19.94	10.49
Soda (Na_2O)	.56	
	99.90	100.56
Specific gravity		3.466

As will be noted, these show very small amounts of alumina as compared with pyroxenes found in terrestrial rocks. The mineral from Busti compares closely with diopside in composition, while that of Shergotty is more nearly that of hedenbergite.

The form and internal structures of meteoric masses are no less interesting than their composition. The crystalline structure of the iron-rich forms I have already referred to. The external form as they come to earth varies almost indefinitely, as shown in plates 2, 4, 6, and 7. From the almost wholly metallic types there is a somewhat abrupt gradation through the stony irons shown in the section of the pallasite from Mount Vernon, Kentucky (pl. 3), to the stony forms in which iron may be almost wholly lacking. In the Mount Vernon pallasite the only essential mineral aside from the metallic compounds is olivine, which appears as rounded blebs rarely, if ever, with crystal faces, held in a mesh or sponge of iron. Between the iron and the olivine there is commonly a thin plate of schreibersite. This iron contains a considerable quantity of lawrencite, which exudes from a freshly cut surface as ferruginous drops of moisture, resulting in some instances in serious disintegrations. Occasional examples of these stony irons have been found in which the olivines are so thoroughly shattered as to constitute a breccia with a metallic cement. Such a one is that from Admire, Kansas, a slab of which is shown in plate 5. It is clearly shown here that the metallic portions are of secondary origin and have been introduced subsequent to the shattering of the olivine. In figure 3 of plate 5 is given a more highly magnified view of one of the interstitial metallic areas of the same meteorite. The area is but some three-quarters of an inch in actual length. The dark, outer portion is mainly olivine, the bright border the nickel-iron, and the dark interior a spongy mass of iron with troilite and lawrencite. The acicular forms extending across the dark area are also of iron. Between the bright border and dark interior is a thin belt of schreibersite, which, however, does not show in the figure.

The nearest approximation in structure among terrestrial rocks to the pallasites is that of the iron-bearing basalts, an example of which from the Nugsauk Peninsula, Greenland, is shown in figure 2, plate 1, in which the white portions are of metal and the darker ground of silicates. The resemblances, on the whole, are quite remote, however.

Passing to the stony meteorites, as those of the Allegan, Michigan, type (fig. 3, pl. 7), we meet with a class of phenomena which are of greater interest to the average petrographer. According to their internal structure and the presence or absence of feldspar as essential constituents, the stones mostly fall into two general groups—the basaltic and chondritic. The first mentioned are made up of lath-shaped plagioclase with augite and olivine or enstatite, as the case



FIGS. 1 AND 2.—POLISHED SLICES OF METEORITE BRECCIA FROM ADMIRE, KANS.

FIG. 3.—ENLARGED PORTION OF SAME.

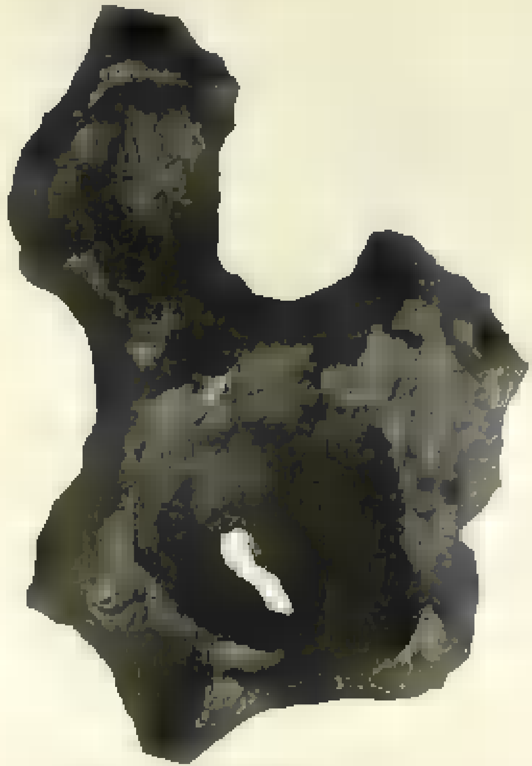
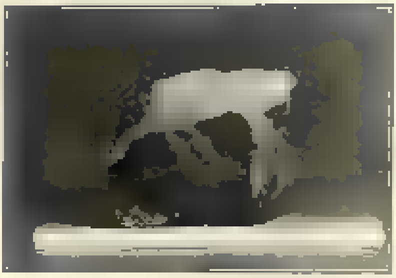


FIG. 1.—CHARACTERISTIC FORM [illegible] CANON DIABLO METEORIC IRON.

FIG. 2.—THE TUCSON OR RING METEORIC IRON.



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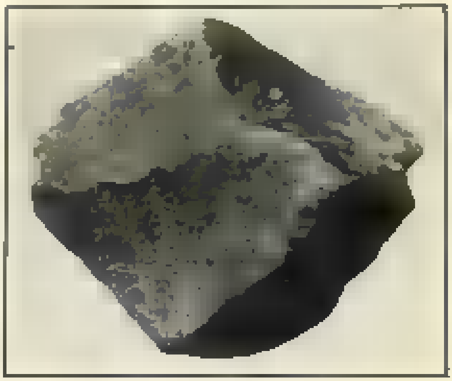

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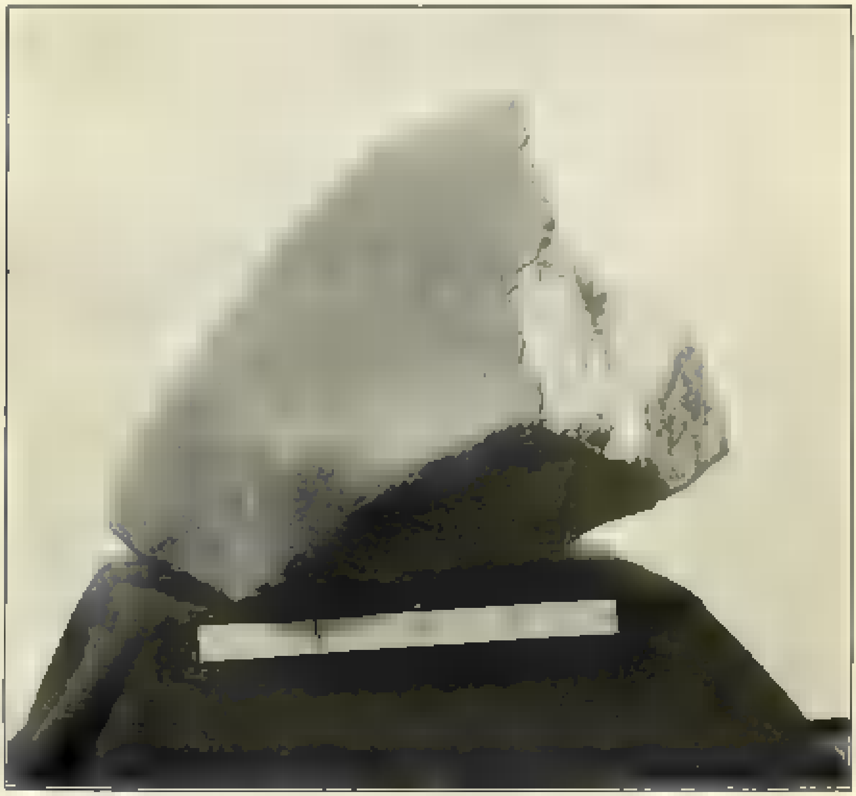
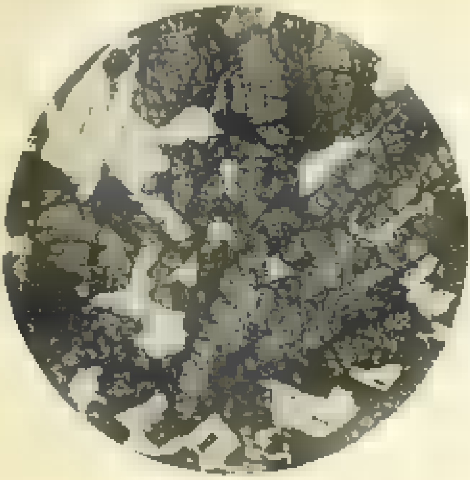


3.

METEORIC STONES FROM (1) FELIX, ALABAMA; (2) NEW CONCORD, OHIO; (3) ALLEGAN, MICHIGAN.



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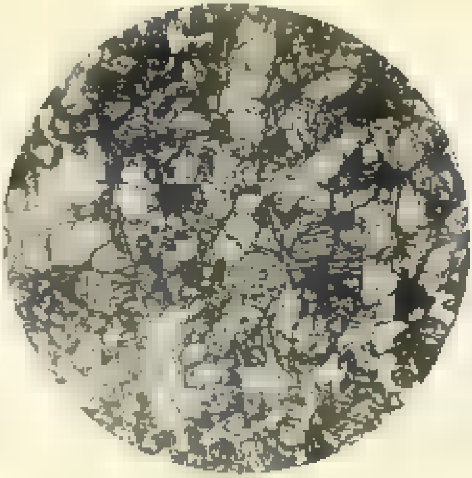

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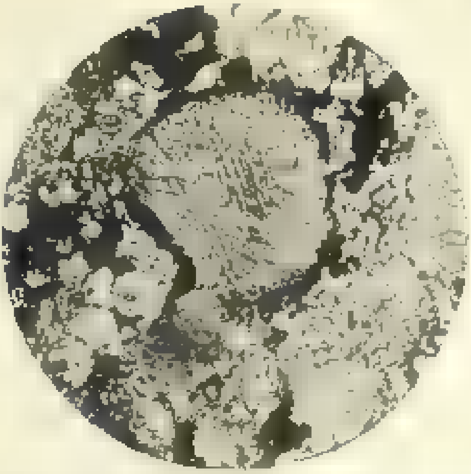

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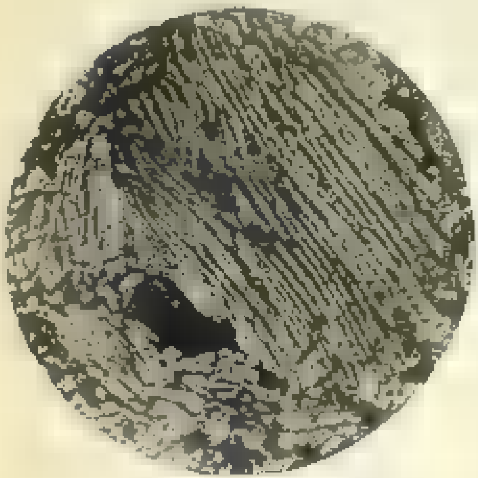

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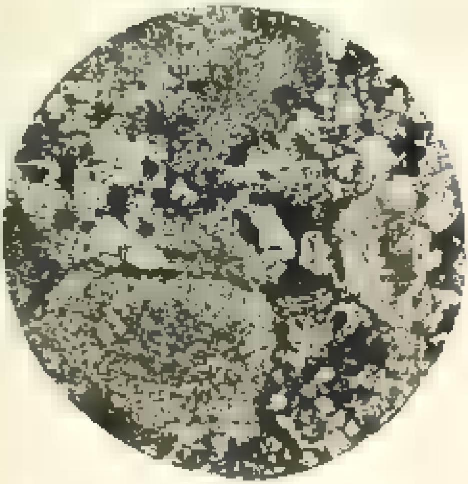


5.

PHOTOMICROGRAPHS OF STONY METEORITES.

1. [illegible] 2. [illegible] 3, 4, 5. Chon- [illegible]

may be. The meteorite of Shergotty, India, is a good illustration of this type (fig. 1, pl. 8). It is, however, not an abundant form. A nearly feldspar-free type closely allied to our terrestrial pyroxenites is shown in figure 2, plate 8, which is from a photomicrograph of a stone which fell at El Nakhla, Egypt, in 1911.

At least 90 per cent of the stony meteorites belong to the class called by Rose "chondritic," from χόνδρος, a grain, in allusion to the rounded and oval bodies or chondrules which are so eminently characteristic (plates 7 and 8). These chondrules consist at times of minerals of a single species, though sometimes of a number of species, which are embedded in a more or less coherent ground of a clastic or crystalline nature. The chondritic material is usually of olivine or enstatite, more rarely a monoclinic pyroxene, and more rarely yet feldspathic, ferruginous or graphitic. Figure 4, plate 8, is from a photomicrograph of a meteoric stone found near Hendersonville, North Carolina. The single chondrule, as shown, is of olivine with a gratelike or barred structure, some of the bars of which, it will be observed, are curved. It is embedded in a fine, granular ground of olivine, enstatite, and monoclinic pyroxene.

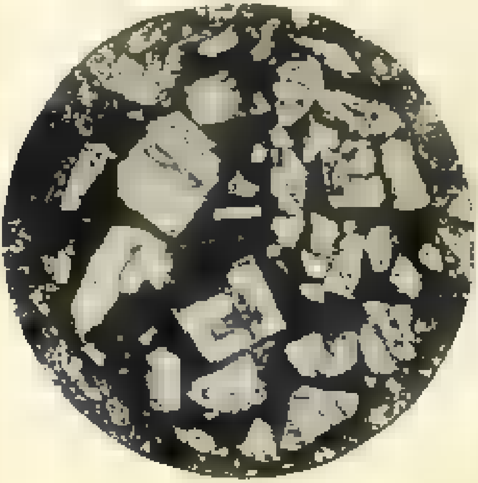
Other examples of chondritic structure are shown in plate 9. Figure 1 is a not unusual type of chondrule in which the pyroxenes are idiomorphic. These porphyritic forms often present the only appreciable amount of pure, glassy base I have thus far observed in meteorites. Often, however, in place of glass, the interstices of the phenocrysts are occupied by a fibrous material evidently of the same mineralogical nature, but not sufficiently individualized to render an optical determination possible. Figure 2 of the same plate shows an enstatite chondrule from the meteorite of Coon Butte, Arizona. This shows a marginal row of independent crystals, but it is to be noted that between crossed nickels the entire chondrule is resolved optically into two portions, the angle of distinction between which is some 30°. Figure 3 from the Elm Creek stone shows a chondrule of enstatite almost perfectly spherical, a not uncommon feature; others show an indistinctly radiating, featherlike cluster of enstatite which is almost comparable with the frost crystals formed during cold mornings on window panes. In figure 4 from the Parnallee, India, stone, the secondary nature of the metallic iron is shown in the manner in which it encompasses and penetrates the mass of the fragmental chondrule.

To those at all well informed it must have already been made evident that we have in meteorites some interesting and wide variations in both composition and structure from those found in terrestrial rocks. So far as yet discovered, the meteorites contain no elements unknown to our earth, although the form of combination may be radically different. Schreibersite, lawrencite, oldhamite, daubree-

lite, and troilite are largely, if not wholly, unknown among terrestrial rocks, while nickel-iron is rare. On the other hand such common terrestrial minerals as free quartz and the compounds of silica with aluminum, calcium, and the alkalies, as orthoclase, albite, nepheline, the micas and amphiboles are rarely, if ever, found in meteorites. Such secondary minerals as serpentine after olivine, talc, chlorite or hornblende after pyroxenes, and indeed any minerals requiring the agency of water or the vapor of water for their production, as zeolites, the micas, tourmalines, etc., are also lacking. It is evident that the meteorites were formed under conditions of a limited supply of oxygen and that they have since their formation been subjected to high temperatures and the reducing power of gases.

All meteorites may be traced unmistakably to an igneous origin, and are of a basic nature, related closely to the basalts, pyroxenites, and peridotites among terrestrial forms. None have as yet been discovered which can be considered as sedimentary, or metamorphic as the word is commonly used, although many of the tufaceous forms have undergone certain changes that may be ascribed to the high temperatures and reducing vapors already referred to. But there is among them nothing comparable with our sand and limestone or argillites, and absolutely nothing of a fossil nature or necessarily indicative of any form of animal or vegetable life, although in years past some of the peculiar radiating and branched forms such as I have shown have been mistaken for and even described and figured as fossil corals and crinoids.

That meteorites as they come to our earth are plainly fragments of preexisting masses has been already stated. Some of these, like those of Stannern and Shergotty, owe their internal structures to direct crystallization from a molten magma. Nevertheless, the structures are by no means similar to those found in terrestrial rocks. As a whole, they show evident signs of hasty crystallization. The Shergotty stone, to be sure, has a somewhat familiar aspect, but it belongs to a type standing almost wholly by itself. So far as I can recall, no structure is found among terrestrial rocks more nearly approaching that of the chondritic meteorite than that of the orbicular gabbro of Davie County, North Carolina, or the kugel granite of Sweden. The resemblance is, however, merely suggestive, and disappears the moment the rock is submitted to critical study. In a large proportion of the kugel chondritic stones the structure of the ground is quite obscure, though the chondrules contain well-developed, as well as radiating and acicular forms, which result from cooling of molten material. The absence of a glassy base from the ground which bears the chondrules is antagonistic to the idea of the origin of both portions through the same agencies and under the



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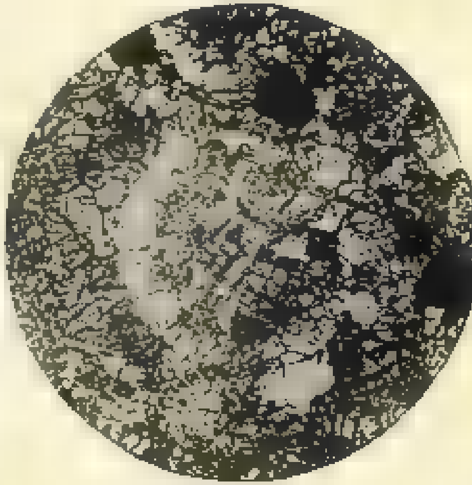

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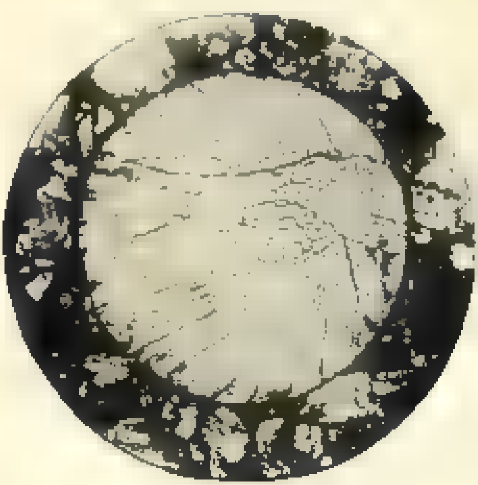

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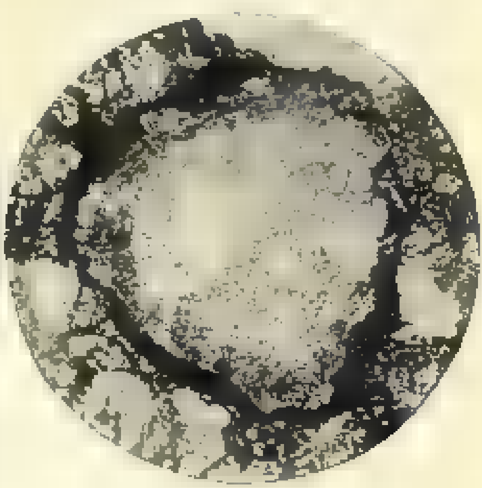

4.

PHOTOMICROGRAPHS OF STONY METEORITES SHOWING CHONDRITIC STRUCTURE.

same conditions. Concerning these chondritic types, Sorby, as long ago as 1866, expressed himself as follows:

> It would, therefore, appear that, after the material of the meteorites was melted, a considerable portion was broken up into small fragments, subsequently collected together, and more or less consolidated by mechanical and chemical actions, among which must be classed a segregation of iron, either in the metallic state or in combination with other substances. Apparently this breaking up occurred in some cases when the melted matter had become crystalline, but in others the forms of the particles lead me to conclude that it was broken up into detached globules whilst still melted (Mezö-Madaras, Parnallee). This seems to have been the origin of some of the round grains met with in meteorites, for they occasionally still contain a considerable amount of glass, and the crystals which have been formed in it are arranged in groups, radiating from one or more points on the external surface, in such a manner as to indicate that they were developed after the fragments had acquired their present spheroidal shape. (Aussun, etc.)

Tschermak, of Vienna, to whom is due some of the best of the early work by modern methods, said, in describing the meteorite of Orvinio, Italy:

> I regard the chondritic meteorites as attrition tuffs and the kugels of the same as such rock particles as, owing to their toughness, have become rounded rather than broken into splinters.

The attrition, he thought, might have taken place in the chimneys of volcanoes. Reusch, of Christiania, from a study of the Tysnes stone, announced, in 1889, his belief that the typical chondrules are but small rounded fragments, the form of which is due to external causes and not to internal structure. He conceived the bronzite kugels to have had originally a conical form, such as is sometimes seen in radiating iron pyrites, the upper surface of the nodules forming the base of the cone. When these become worn down by attrition, the point breaks away, and hence in the section the radial point always lies without the kugel. F. Rinne, writing as late as 1895, compares the chondrules of meteorites to certain bodies observed by him in the volcanic tuffs of Westphalia. These he describes as showing a yellow-brown, glassy base with sharply defined "einsprenglings" of olivine and monoclinic pyroxenes. These tuffs, however, show gas cavities in this glassy base, while the meteorites do not. The structure observed in the Kernouvé meteorite, and which I have referred to in that of Hendersonville, North Carolina, where larger granules of silicate minerals are surrounded by finer, dustlike material with no interlocking or true glassy base, he regards as a breccia due to crushing and a partial refusion or a sintering, in this agreeing with Tschermak. He claims to have produced similar forms by sintering an olivine sand.

My own views on the subject have undergone no material change since expressed in an article by Dr. H. N. Stokes and myself in 1900, when describing the meteorite of Allegan, Michigan, a somewhat

pronounced example of the friable kugel chondritic type. These were substantially as follows:

The general structure of the Allegan stone can, I believe, be accounted for only by regarding it as an agglomerate of chondrules embedded in a fragmental ground mass or matrix, the materials of which were derived from the trituration of other chondrules. Obviously, if the stone is a product of crystallization in mass, the chondrules are the products of the earliest cooling and, judged by the standards of terrestrial petrography, should be the most highly crystalline, while the base in which they are embedded might be glassy or crystalline, according to conditions. In reality the reverse is the case, and, so far as I have observed, there is never any true glassy base in metorites of this type. The subject of the spherules in liparites has been pretty thoroughly worked out by Cross and Iddings; and while it is easy to conceive of the abrupt transition from a wholly or partially crystalline spherule to a glassy base, as sometimes seen in spherulitic rocks, it will, in the present condition of knowledge, puzzle any petrographer to account for an equally sharp transition from a glassy spherule (chondrule) to a base composed wholly of crystalline particles, as shown in many meteorites. Even could we account for such anomalies of crystallization, the presence of fragmental chondrules, of chondrules which were fragments at the time of the final consolidation of the stone, would yet remain to be explained. The forms shown in figure 4 were all carefully picked from the rock without crushing. That they are original fragments, *i. e.*, not due to fracturing in place, is shown by the dull, lusterless character of the surface of fracture, and, further, by the fact that in no case was the remainder of the chondrule represented by one of these pieces found in the vicinity. No. 1, in figure 4, represents a complete chondrule, No. 2 one but slightly corroded, while the others are plainly fragmental. No. 5 is one of the most striking illustrations, being that portion of an enstatite chondrule, some 8 millimeters in diameter, embedded in a fine clastic ground. The flat surface of fracture is unquestionably an old one. No. 6 shows a side view of the same chondrule. In other cases as in 3 and 4 the fractures are old and show abraded surfaces. Nos. 2 and 5 are plainly those of elongated chondrules that have been broken across. No. 1 is a peculiarly suggestive form having the appearance of a once molten globule which, on cooling, contracted, producing the concavity shown. Such forms lend support to an idea advanced

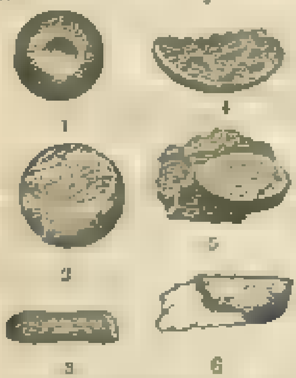

FIG. 4.—CHONDRULES FROM ALLEGAN METEORITE.

by Sorby to the effect that "some at least of the constituent particles of meteorites were originally detached glassy globules, like fiery rain." It is possible to conceive that these chondrules, first as blebs of molten matter and then as consolidated particles, may have been triturated in the deep throat of some volcano. The spherical form I can not, however, regard as being wholly due to trituration, a view held by some writers, but rather to their original molten condition.

The manner in which the metallic portions are wrapped about and even injected into the silicate particles suggests the probable reduction of the iron, not merely since their original crystallization, but even since the reconsolidation of the detritus resulting from their disintegration.

But one word more. It has long seemed to me that these bodies have not received the attention they merit from the standpoint of world history.

If we consider, I will not say accept, either the meteoric or planetesemal theory of world origin, we are bound, as it seems to me, to regard the meteorites as world matter.

If so regarded, we are confronted at once with the general basic nature of the original magma from which they were derived. Generously leaving out of consideration the metallic constituents and having regard only for the silicates, it appears that in but a few instances does the silica rise above 50 per cent. Alumina is likewise low, only in the basaltic forms rising even as high as 14 per cent. The percentage of lime is also low, while the alkalies are rarely present in amounts up to even 1 per cent. Magnesia, on the other hand, is almost invariably abundant, the amount at times rising as high as 40 per cent. These facts are well brought out in the accompanying table from a former publication.[1] Column I represents an average of 53 analyses with the exceptions noted. Column II shows the average composition of terrestrial igneous rocks, after Clarke, and column III that of the entire lithosphere.

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[1] Mem. Nat. Acad. of Sciences, vol. 14, 1916, p. 28.

Average Composition of Stony Meteorites Compared with Terrestrial Rocks.

	I	II	III		I	II	III
SiO_2	38.65	59.93	59.85	MgO	23.67	3.83	3.77
TiO_2	[1].13	.76	.73	MnO	[7].30	.10	.09
SnO_2	None.			SrO	None.	.04	.04
ZrO_2	None.	.05	.03	Na_2O	[8].97	3.40	3.29
Al_2O_3	2.58	14.97	14.87	K_2O	[9].23	2.90	3.02
Fe_2O_3		2.58	2.63	Li_2O	Trace.	.01	.01
Cr_2O_3	[2].47	.05	.06	H_2O (ign.)	[10].73	1.94	2.05
V_2O_3	Trace.	.02	.02	P_2O_5	[11].26	.28	.25
Fe	11.96			S	[12]1.90	.11	.10
Ni	[3]1.13			Cu	[13].014		
Co	[4].05			C	[14].15		.03
FeO	14.53	3.42	3.35	Cl	[15].06	.06	.06
NiO	[5].34	.03	.03	F	(?)	.10	.10
CoO	[6].06			CO_2	(?)	.18	.10
CaO	2.03	4.79	4.81				
BaO	None.	.11	.10		100.054	100.00	99.98

[1] Average of 16 dets.
[2] Average of 42 dets.
[3] Average of 20 dets.
[4] Average of 11 dets.
[5] Average of 10 dets.
[6] Average of 6 dets.
[7] Average of 37 dets.
[8] Average of 19 dets.
[9] Average of 44 dets.
[10] Average of 15 dets.
[11] Average of 44 dets.
[12] Average of 61 dets.
[13] Average of 16 dets.
[14] Average of 6 dets.
[15] Average of 5 dets.

Now with our present knowledge regarding the composition of the earth's crust, of the relative proportional abundance of the basic and acidic rocks, I feel that it is self-evident that no amount of chemical differentiation of such a magma as that presented by the meteorites could bring into existence such a body as that of our earth *so far as its composition is yet revealed*. It is to be noted, however, that we have no direct evidence as to the chemical nature of meteoric matter that may have come to the earth in past ages. Incidentally, I will mention one fact that has often impressed itself upon me. Those who affirm that the salt of the ocean is wholly secondary, have no difficulty in finding a source of the sodium through the ordinary atmospheric decomposition of sodium bearing silicates. Not so, however, with the chlorine, and as with the exception of comparatively small amounts of this element carried by such minerals as sodalite and some of the apatites, there are known no original chlorine-bearing minerals, it is difficult to account for its relative abundance in oceanic waters. In the comparatively abundant meteoric mineral lawrencite we have at least a suggested source, and that too, in a form easily broken up when exposed to atmospheric conditions.

CORALS AND THE FORMATION OF CORAL REEFS.[1]

By Thomas Wayland Vaughan.

[With 37 plates.]

CONTENTS.

INTRODUCTION.

Corals have long attracted the attention and excited the interest of scientific men, observant laymen, and poets. For some hundreds of years they were thought to be marine plants and were termed "Zoophytes," a name said to have been given them in the sixth century by Sextus Empiricus and Isodore of Seville. Notwithstanding that Ferrante Imperato in 1599 advocated that corals were animals, naturalists persisted in believing that they were plants until

[1] In the present article only a few specific references to the literature on corals and coral reefs have been introduced. However, in my memoir entitled "Fossil corals from Central America, Cuba, and Porto Rico, with an account of the American Tertiary, Pleistocene, and Recent coral reefs," in press as a part of U. S. National Museum Bulletin 103, I have given fairly full bibliographic citations and have called attention to certain publications, particularly those by W. M. Davis and R. A. Daly, in which there are elaborate reviews of the literature on coral reefs.

Peysonnel announced the results of his laborious investigations in the West Indies, and even after his observations were published in 1753, a few perverse individuals continued to adhere to the old views. It now seems strange that Peysonnel's researches constituted one of the important advances in our knowledge of the animal kingdom.

Of the early savants, Patrick Brown in his "Civil and Natural History of Jamaica," 1756, Seba in his "Locupletissimi rerum naturalium Thesauri accurata descriptio," 1758, Knorr in his "Deliciae selectae naturae," 1771, and many others described and figured many corals; and much pleasure may be derived from the text and the carefully executed figures of these authors. One of the most delightful of story-tellers and lyric poets, Adelbert de Chamisso, exiled from France as a result of the French Revolution and a refugee in Germany, was one of the early contributors to coral-reef theories. He described one species of stony coral and published exquisite figures of it based on his own drawings. Though the enthusiasm of many of the early writers on this subject is inspiring and their charm is great and though the temptation is strong to yield to their spell and consider the subject only as they so fascinatingly present it, attention must be diverted from them and directed toward the objects themselves.

WHAT ARE CORALS?

Since the days of Peysonnel all informed students, except the few perverse individuals to whom allusion has been made, have believed that corals are not merely animals but that they are animals closely akin to the sea anemones. Like sea anemones, they are, at least while young, more or less cylindrical in form; the lower end, called the foot, is attached to some object; around the margin of the flattish upper end there are tentacles that can be extended or retracted; and near the middle of a flattish area within the tentacles there is a slit-like mouth that can be widely opened or closely shut. Below the fleshy floor between the tentacles and the mouth there are folds of soft tissue, known as mesenteries, that are attached to the wall on their outer ends, but on their inner ends they are free below a rather short tube, called the gullet or esophagus. On the edges of the mesenteries there are often curled filaments, called mesenterial filaments. Figures 1 and 2 on plate 1 are illustrations of two Blaschka glass models of sea anemones.

One of the peculiarities of corals and related animals is that the outer surface of the animal tissue, including the tentacles and the mesenterial filaments, are beset with lasso stinging-cells (see text fig. 4, p. 207), each of which may shoot out a small dartlike object that at one end is attached by a thread. Another peculiarity is that their outer surface secretes slimy mucus; and a third attribute is that their sur-

faces are covered with small short processes, termed cilia, which under certain conditions beat so as to move the mucus and whatever may be embedded in it toward the mouth, while under other conditions they beat so as to move things away from the mouth.

Sea anemones and corals are alike in the characters so far considered. They differ in that sea anemones have only soft tissues, while the lower surface of corals secretes a skeleton, called the corallum, composed mostly of carbonate of lime. Coral larvae, called planulae, are small, pear-shaped or cylindrical objects, about half a millimeter in diameter and about a millimeter long, and their outer surface is covered with cilia by means of which they can move rapidly. After a time, ranging from a day or two to two or three weeks, the larval corals settle and attach themselves to some object.

FIG. 1.—LARVAE OF THE CORAL FAVIA FRAGUM (ESPER), MUCH ENLARGED. AFTER DUERDEN. THE VARIOUS FORMS OF THE LARVAE IMMEDIATELY AFTER EXTRUSION ARE REPRESENTED. A IS VIEWED AS A TRANSPARENT OBJECT; B TO E ARE REPRESENTED AS SEEN BY REFLECTED LIGHT. THE EXTRUSION OF CELL DEBRIS THROUGH THE ORAL APERTURE OF A IS SHOWN.

At first a flat basal plate is secreted by the bottom end, and on this are laid down radial plates that grow upward within or between the mesenterial folds. Above each of the radiately arranged plates, known as septa, there is a tentacle. At their outer ends the septa are joined together by a wall, differing in character according to the kind of coral, and at the inner ends of the septa there is usually, but not always, a central columella, which likewise differs in character according to the kind of coral. In the spaces between the septa peculiar structures that are of much value in classifying corals may develop.

Some corals remain simple, that is solitary, throughout their lives (some of these are shown on pls. 3 and 12 to 14); while others multiply asexually and form colonies. There are two kinds or methods of asexual reproduction recognized by students of these organisms. One of these methods, termed budding or gemmation,

is by a bud appearing on the surface of the soft tissues outside the circle of tentacles (pl. 2, fig. 1): the other method, known as fission, is by a mother coral polyp dividing equally or unequally and forming two or more polyps (pl. 2, fig. 2). Budding or fission may be repeated until from an initial polyp only 1 or 2, or perhaps 5 millimeters in diameter, a colony, a compound coral, many feet in diameter may result, with thousands of individual polyps, each having its own more or less clearly recognizable mouth, but all joined together by communal soft tissue known as coenosarc.

Corals that remain simple may be small, 5 or 6 millimeters (about one-fifth inch) in diameter, or they may be rather large, up to as much as 250 millimeters, nearly a foot, in diameter, as in some species of the genus *Fungia* (pl. 3, figs. 1, 1a). The range in size of the individual polyps in compound corals is from less than 1 millimeter (0.039 inch) in diameter up to as much as 2 or 3 centimeters (0.78 or 1.18 inch), and perhaps more.

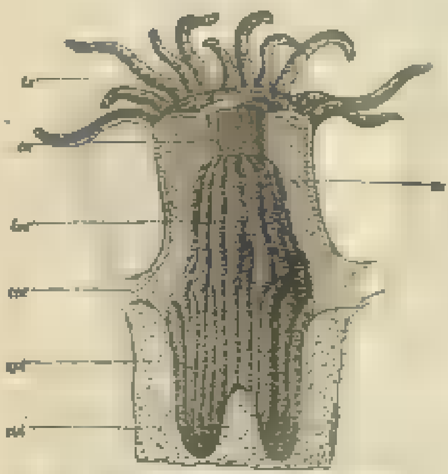

Fig. 2.—Enlarged longitudinal section of Astroides calycularis (Pallas). After Lacaze Duthiers. tr, tentacles; oe, oesophagus; me, mesentery; fm, mesenteric pouches; coe, coenosarc; spt, septum; col, columella.

Coral colonies are very diverse in form—they may be low, flat plates, closely adherent to the basal support; they may be cushion-shaped; they may form more or less perfect hemispheres or spheres; or the outer surface may be variously lobed. Some corals form simple or divided columns; others form elongate, round branches, which range from only a few millimeters to several centimeters in diameter; the branches of other corals are more or less compressed and platelike. Other growth-forms are erect or subhorizontal, thick or thin plates and vases, which may be small and shallow or large and deep. Some colonies are tuftlike. In colonies that are formed by budding, the individual corallites and polyps are usually subcircular in outline and are separated from one another by interspaces that range in width from mere dividing walls up to several centimeters across. But in colonies formed by fission, the corallites often occur in series which may contain two or three, or very many corallites in rows; when the series are long they may wind and twist so as to warrant bestowing such names as *Maeandra*

and *Meandrina* on certain genera. One genus of corals in which the corallum forms tall, more or less divided columns, has long, winding series and is appropriately named *Dendrogyra*. In such series the polyp mouths occur along longitudinal depressions, called valleys, which may be narrow or wide, shallow or deep, and adjacent valleys may be close together with very narrow interspaces or they may be relatively far apart.

It will be shown in remarks to follow that the growth-form is of much importance in considering the relations of corals to the physical conditions under which they live. The flattish, cushion-shaped, and hemispherical corals, that are attached by wide bases, have the strongest structures; those corals composed of thick plates or thick platelike branches rank next in strength; while those that form thin, erect laminæ and slender, long branches are the weakest. Some corals that have rather strong skeletons need to be classed with the corals with weak skeletons, so far as their habitats are concerned, for they live either free on the sea bottom or are very weakly attached.

The corals so far considered are those known as the Madreporaria. Their soft tissues secrete nearly pure white skeletons composed almost entirely of carbonate of lime; there are pitlike calices or valleys in the skeleton; and more or less distinctly radial septa are present. The hard skeleton is called "coral" and this is the kind of "coral" from which coral reefs derive their name. Before speaking of another kind of coral, it will be stated that the tentacles of the Madreporarian corals are either simple (see pl. 17 and text fig. 2) or are bifurcate or trifurcate—they are *never* pinnate; and it will also be said that in the Madreporarian corals now living, the septa and mesenteries are arranged on a plan of six or in multiples of six, except where the plan has been obscured by fission. Because of this arrangement of septa and mesenteries, this group of corals is called *Hexacoralla*. Ages ago, geologically speaking, the predominant corals had their septa arranged on a basal plan of *four* or *multiples of four* and these have been called *Tetracoralla*, the other highest subdivision of the Madreporaria.

The Alcyonaria, constituting a group of corals of the same rank as the Madreporaria, comprise the precious coral, *Corallium rubrum*, and other species from which jewelry is made, the sea fans, sea feathers, and sea whips, some of which are among the most beautiful objects in the ocean. The tentacles of these corals are pinnately fringed or plumose, and, because their mesenteries and tentacles are arranged on a plan of eight, they have been called *Octocoralla*. The skeleton of the Alcyonaria is unlike that of the Madreporaria, in that it usually consists of a horny axis, more or less completely calcified, surrounded by horny material in which spicules are embedded.

The skeletons of Alcyonaria of this kind further differ from those of the Madreporaria in possessing, according to F. W. Clarke and W. C. Wheeler, from 6.18 to 15.73 per cent of carbonate of magnesia. In the red organ-pipe coral, genus *Tubipora* (pl. 4, figs. 1, 1a), the spicules are sufficiently cemented together to form tubes. The skeleton of the blue coral, *Heliopora coerulea* (pl. 4, figs. 2, 2a), looks very much like one of the Madreporaria, and it is composed of almost pure carbonate of lime, but the polyps have the anatomical characteristics of the Alcyonaria.

Fig. 5.—*Corallium rubrum* Lamarck. After Lacaze-Duthiers.

One of the hydroids, *Millepora* (pl. 2, figs. 3, 3a), is usually considered with the corals, although zoologically it is not one of them. The figures of the skeleton show that it has no distinct septa, and that there are two kinds of pores corresponding to two kinds of polyps, also called zooids. The larger pores, the gastropores, lodge the larger nutritive polyps; while the smaller pores, dactylopores, lodge the smaller, the food-capturing, zooids. The skeleton of *Millepora*, according to Clarke and Wheeler, is composed of almost pure carbonate of lime.

DIFFERENCES IN THE CORALS ON THE LAGOON (THE QUIET WATER) AND ON THE EXPOSED (THE ROUGH WATER) SIDES OF A CORAL REEF.

Darwin in his Structure and Distribution of Coral Reefs, [3] gave an excellent description of the difference between the corals in the lagoon of Keeling atoll and those on the exposed reef. A few years ago Dr. F. Wood Jones spent 15 months in the Cocos-Keeling Islands, and in his book, Coral and Atolls, produced a far more detailed account of the relations of the corals in those islands to their environmental conditions than that of Darwin, but what Darwin said is correct. Dr. Wood Jones sent me his collection, which is now the property of the United States National Museum, and I have been able to publish a detailed account of it.[4] The Cocos-Keeling Islands are classic ground for the students of reef corals and coral reefs, and it seems appropriate to begin the consideration of the relations of

[3] See 3d ed., pp. 1–10, 1889.

[4] Vaughan, T. W., Some shoal-water corals from Murray Island (Australia), Cocos-Keeling Islands, and Fanning Island: Carnegie Institution, Washington, Publ. 213, pp. 49–234, pls. 20–93, 1918.

corals to their environment with an account of conditions there. The following table shows the relations:

Relations of growth-form of Cocos-Keeling corals to habitat.

Habitat.	Free corals.	Fragile branches or folia.	Stout branches and lobate columns.	Growth-form massive.
Lagoon	2	11	3	1
Barrier pools and barrier flat	2	6 (mostly on lagoon edge of flat)	4	5
Exposed side of barrier			3	13

Within the lagoon free corals or corals that form fragile branches or folia are predominant; on the barrier flat and in the barrier pools the forms with stronger skeletons are more numerous; while on the exposed barrier there are only corals that have a massive growth-form or are composed of stout branches. One of the species, *Pocillopora elegans* Dana, which forms compressed branches, occurs within lagoons and on barriers. The branches of the specimens in the lagoon are tall and rather weak, while specimens on the barrier have the branches aborted into slightly protuberant nodules. Plate 6 illustrates a corallum of the lagoon kind, and plate 5, figure 2, illustrates a specimen Dr. Wood Jones collected on the Cocos-Keeling barrier.

Six specimens of *Pocillopora bulbosa* Ehrenberg taken by Dr. Wood Jones from a floating log are very interesting in this connection (pl. 5, fig. 1). He says regarding these specimens:

> In the lagoon, a large portion of a tree trunk was floated, and made fast to an anchor and chain; the wood was used to float a ship's moorings, and remained just two years in the water. When it was removed in 1906, several colonies of *Pocillopora* had started growths upon it, and they had taken up different positions around its circumference. The colonies growing above were flattened bosses; those on the sloping sides showed more tendency to branch; and those below its convexity were delicate branched forms.
>
> Now the environments of these colonies were very different, and they were absolutely constant. At all stages of the tide waves broke upon its upper surface, whilst the sides were in gently moving unbroken water, and the bottom was in comparative calm. * * *

Dr. A. G. Mayer made a very interesting collection of corals at Murray Island, Australia, and I have described them in my paper above cited. Preceding my paper, Doctor Mayer has given in the same volume an account of the ecology of the Murray Island reef, in which he presents a statistical statement of the number of coral colonies according to species in successive squares across the reef. I based the following table on Doctor Mayer's collection:

Table showing distance from shore, depth of water, character of bottom, number of species, and growth form of the colonies, for each station on line I, southeast reef, Murray Island.

Distance from shore (in feet).	Depth of water at low tide (in inches).	Character of bottom.	Number of species at each station.	Number of species according to growth form.		
				Fragile branches and free disks.	Stout branches.	Massive or incrusting.
200	2 -4	Hard limestone mud over bare rock	1	...	...	1
300	4.5-5	Firm limestone mud	7	3	...	4
400-500	6 -12	Sand and mud, rock	10	3	...	7
600-650	7.5-10	Sandy	18	7	...	11
800-850	10 -11	Broken coral	[a] 20	6	1	12
1,000-1,050	14 -17	Rocky	21	10	1	10
1,200-1,250	12 -16	Rocky	19	6	3	10
1,400-1,445	11 -15	Rocky, broken coral	24	10	2	12
1,600-1,675	10 -12	Hard, rocky, broken coral	33	4	2	27
1,720-1,775	2.5-3	Hard, rocky, with crevice-like tide pools	13	...	6	7

[a] *Acropora prolifera* (Brook), which is of decided corymbose growth form, is not counted in the tabulation.

Comparison of this with the preceding table reveals precisely the same principles.

The collection made by Doctor Mayer at Murray Island contains an excellent illustration of the variation of *Stylophora pistillata* (Esper) according to environment. The branches of a specimen from a depth of 18 fathoms, northwest of Murray Island, where the water is not violently agitated, are slender, elongate, and fragile (pl. 7, fig. 1), while a specimen from the exposed reef has very short, stumpy branches (pl. 7, fig. 2). Plate 8, figure 2, illustrates *Porites porites* from the exposed reef at Tortugas, Florida, while plate 8, figure 1, illustrates the growth form assumed by a fragment broken from the exposed reef and then attached to a terra-cotta disk and planted within Tortugas lagoon.

In shallow water, corals which have fragile skeletons or which are weakly attached to the bottom predominate in lagoons, where the water is not violently disturbed; and usually conditions favorable for the life of corals having these kinds of growth habits are present outside lagoons in depths between 18 and 25 fathoms. But on the exposed sea-sides of reefs, where the surf is strong and storm waves break, all the corals have strong skeletons, mostly of massive growth form. If the same species of branching coral occurs both in places protected from the beat of the surf and in those exposed to the breakers, the colonies in the exposed situations adjust themselves to their environment by strengthening their skeletons. The preceding paragraphs show that these adjustments take place in the Cocos-Keeling Islands, on the Great Barrier of Australia, and in Florida, and warrant the conclusion that the phenomena are of general occur-

rence. As there are, particularly along the sides of channels through which water flows into and out of lagoons, situations intermediate in condition between those in the lagoons and those on the exposed sea-sides of reefs, there are areas in which there is more or less commingling of the two kinds of corals, and in them both massive reef-building forms and fragile lagoon forms live side by side.

RELATION OF CORALS TO DEPTH OF WATER.

A great deal of information has been accumulated on the relation of corals to depth of water. Among those who have particularly studied this subject are Darwin, Dana, Pourtalès, Quelch, Moseley, Stanley Gardiner, and myself. Usually massive reef builders are mostly found in water 27 meters or less in depth, but some species extend to depths between 37 and 48 meters, and a few reach depths as great as 74 meters. The available evidence indicates a depth between 37 and 46 meters as the maximum at which a true coral reef will form.

At depths slightly greater than 46 meters, between 46 and 74 meters, there are in coral-reef areas corals that differ somewhat from the shoal-water fauna and from the true deep-sea corals. These corals naturally resemble more closely those found in the deep water of the lagoons than those on the exposed sides of reefs or the flats just behind exposed reefs. Stanley Gardiner appears to have been the first clearly to recognize this bathymetric faunal zone, and in his work on the Maldive and Laccadive Archipelagoes very properly emphasized its importance. In my own work on the living corals of the Hawaiian Islands, I recognized the presence of a rather distinctive fauna at these depths. Illustrations of it are given on plates 9-11.

Between 74 and 183 meters in depth corals of deep-sea facies commingle in the Hawaiian Islands with the fauna found principally between 46 and 74 meters in depth. Deep-sea corals, those found in water 183 meters or more in depth, are mostly simple, cup corals, and many have very delicate, fragile, even lacelike skeletons. Several species from the Hawaiian Islands are illustrated by plates 12–15. A species that closely resembles the one illustrated by plate 14, figures 3, 3a, was dredged off Callao, Peru, in water 3,209 fathoms (=19,254 feet=5,892 meters) deep. Other deep-sea corals are compound forms that have delicate, elongate, attenuate branches. Three species with this kind of growth habit are illustrated by plate 15.

The following tables present the results of a study of the distribution of Hawaiian corals according to depth. Similar relations prevail in the Indian Ocean, the Central Pacific, and in the Gulf of Mexico and the Caribbean Sea. Although these tables apply specifically to the Hawaiian Islands, they really illustrate certain of the broad principles underlying the relation of coral faunas to depth of water.

Bathymetric distribution of corals in the Hawaiian Islands—Table showing the numerical distribution of forms according to depth.

(*Depths in meters.*)

Depth in meters	0–40	40–74	74–183	183–366	366–549	549–732	732–915	915–1,098	1,098–1,281	1,281–1,464	1,464–1,647	1,647–2,105
Number of forms found at that depth	77	14	7	21	13	8	0	0	1	0	2	1
Number of forms confined to that depth	70	5	2	14	6	5			0	0	1	1
Number of forms ranging into the next deeper	7	2	4	6	5	0			0	0	0	
Number of forms occurring in next shallower		7	2	4	6	3			0		0	
Number of forms occurring in both shallower and deeper water		0	1	3	1	0						

Bathymetric distribution of coral genera in the Hawaiian Islands.

(*Depths in meters.*)

0–46	46–74	74–183	183–366	366–549	549–732	732–915	915–1,098	1,098–1,281	1,281–1,464	1,464–1,647	1,647–2,103
Pocillopora.	Pocillopora.	Madracis.	Flabellum.	Flabellum.	Desmophyllum.	None.	None.	Flabellum.	None.	Flabellum.	Bathyactis.
Leptastrea.	Pavona.	Fungia.	Placotrochus.	Gardineria.	Caryophyllia.					Caryophyllia.	
Cyphastrea.	Leptoseris.	Leptoseris.	Paracyathus.	Desmophyllum.	Cyathoceras.						
Coelastrea.	Montipora.	Stephanophyllia.	Deltocyathus.	Paracyathus.	Ceratotrochus.						
Fungia.	Porites.	Balanophyllia.	Caryophyllia.	Trochocyathus.	Madrepora.						
Pavona.			Cyathoceras.	Caryophyllia.	Mussa?						
Leptoseris.			Anthemiphyllia.	Cyathoceras.	Anisopsammia.						
Stephanaria.			Madracis.	Madracis.							
Psammocora.			Leptoseris.	Leptoseris.							
Dendrophyllia.			Stephanophyllia.	Anisopsammia.							
Montipora.			Endopachys.								
Porites.			Balanophyllia.								
Alveopora.			Dendrophyllia.								
TOTAL NUMBER OF GENERA.											
13	5	5	13	10	7	0	0	1	0	2	1

RELATION OF CORALS TO TEMPERATURE.

In the foregoing pages the relations of corals to violently agitated or relatively quiet water and to depth of water have been particularly discussed. The relations of corals to the temperature of the water will now be considered, and it will be introduced by a table showing the distribution of the genera of Hawaiian corals according to temperature. The surface temperatures in this table are for the period between March 27 and August 29, 1902, and, therefore, do not represent the minimum temperature for the year. The temperature relations of reef-corals will be considered later. If this table is compared with the table showing the bathymetric distribution of coral genera in the Hawaiian Islands, it will be evident that the names in the first column of each table are the same. A further examination of the table showing the distribution of genera according to temperature will reveal that a temperature of about 22.8° C. is the boundary between the shoal-water and the deep-water faunas. The names of the genera that were obtained at temperatures above 15.6° C., but not so high as 22.8° C. and above 4.5° C., are those that appear in the columns 183 to 732 meters in depth; the genera dredged between temperatures of 4.5° and —1.12° C. were those collected between 1,464 and 2,105 meters in depth. The temperature of the deep-sea fauna ranges between somewhat less than 22.8° C. (about 15.6° C.) and —1.12° C., with the maximum development between 10° C. and 4.5° C.

Distribution of genera of corals according to temperature in the Hawaiian Islands.

25.6° to 22.8° C.	22.8° to 15.6° C.	15.6° to 10° C.	10° to 4.5° C.	4.5° to —1.12° C.
Pocillopora.	Flabellum.[1]	Flabellum.	Flabellum.	Flabellum.
Leptastrea.	Placotrochus.[1]	Cyathoceras.	Gardineria.	Caryophyllia.
Cyphastrea.	Paracyathus.[1]	Madracis.	Desmophyllum.	Bathyactis.
Coelastrea.	Caryophyllia.[1]	Stephanophyllia.	Paracyathus.	
Fungia.	Cyathoceras.[1]	Balanophyllia.	Deltocyathus.	
Pavona.	Anthemiphyllia.[1]		Trochocyathus.	
Leptoseris.	Madracis.[1]		Caryophyllia.	
Stephanaria.	Fungia.[3]		Cyathoceras.	
Psammocora.	Leptoseris.		Ceratotrochus.	
Dendrophyllia.	Stephanophyllia.[2]		Madrepora.	
Montipora.	Balanophyllia.[2]		Madracis.	
Porites.	Dendrophyllia.[1]		Mussa? sp. juv.	
Alveopora.			Leptoseris.	
			Stephanophyllia.	
			Endopachys.	
			Balanophyllia.	
			Dendrophyllia.	
			Anisopsammia.	
Total number of genera.				
13	12	5	18	3

[1] Not obtained at a temperature so high as 21° C.=70° F.
[2] Not obtained at a temperature so low as 21° C.=70° F.
[3] Temperature range doubtful.

North and south of coral reef areas it seems that the deep-sea corals live in shallower water, because the temperature of the water at and near the surface in higher latitudes is colder than at the surface in the Tropics. For instance, some years ago a species of *Caryophyllia*, one of the cup corals, which was collected along the shore in Alaska, was submitted to me by the United States Bureau of Fisheries. It is an unnamed species, but in its general aspect it resembles the deep-sea forms of the Tropics. There is much scattered evidence of this kind, for example, the corals living on the shores of southern California, but it has never been assembled and systematically presented. There is in the United States National Museum a large amount of material, for which there are records of the depth and temperature of the water and the character of the bottom, that could serve as the basis for such a study. It is my belief that the great gap in present information on coral faunas is the dearth of information on the relations between the deep-sea faunas of the Tropics and the shoal-water faunas of the colder parts of the ocean, both northward and southward from the Tropics. For a long time it has been my desire to make a special study of this important problem, and, unless some one else undertakes it, I still hope to be able to give it the attention that, in my opinion, it deserves.

With regard to the temperature relations of reef-forming corals, it will be said that, except on very shallow flats where the water is stagnant at times and the temperature at such times may range between 33° and 38° C., the upper limit of the temperature endurance of such corals is rarely reached. It is therefore rather to the lower limit of temperature that reef-corals can withstand, that attention should be directed.

A series of experiments, conducted by A. G. Mayer to ascertain the higher and lower limits of temperature the common corals around the Tortugas can endure, indicate that a lowering of the temperature to 13.9° C. would exterminate the principal Florida reef corals, while the most important inner flat corals would survive. He obtained similar results on the corals around Murray Island, Australia. But, actual reef records show that reef corals do not naturally withstand so much cooling as in the laboratory experiments.

Temperature records made at lighthouses along the Florida reef, communicated to me by Dr. H. F. Moore of the United States Bureau of Fisheries show that vigorous reefs will endure a temperature as low as 18.15° C., the minimum at Carysfort Light between the years 1879 and 1899; but at Fowey Rocks, where the minimum drops to 15.0° C., although there are some corals, there is no thriving reef. The species found at the north end of the reef line are those which Mayer's experiments showed capable of withstanding the lowest temperature. The temperature records for the reef line

indicate 18.15° C. as the minimum temperature which a reef will survive—this is 1.85° C. lower than the figure given by Dana. It is not probable that a reef could withstand a continuous temperature so low as this. Wherever the depth of water is great enough to lower the bottom temperature below 18.15° C., more probably about 22° C., reef corals will not live. This temperature appears to be attained around the Hawaiian Islands within a depth of 183 meters. According to Agassiz's "Three Cruises of the Blake" the bottom temperature in the Gulf of Mexico and the Caribbean Sea is usually too low for the growth of reef corals at a depth of 183 meters, and in places it is too low at a depth of 87 meters. Recent records of temperature near Bermuda, the Bahamas, and Florida, show that in those areas the temperature at 300 meters is uniformly too low for the life of reef corals: it is usually too low at 200 meters; and occasionally too low at 100 meters, in an area where the surface temperature is high enough for the life of reef-forming corals.

RELATION OF CORALS TO SEDIMENT.

One of the important factors affecting the life of corals is their relation to sediment. Of course any coral permanently buried in sediment would be killed, but nearly all corals can remove some sediment from their surfaces, and some can rid themselves of considerable quantities. The outer-reef corals proper have their surfaces kept clean by the movement of the water, that is, by waves, surf, and currents; but as the species living on the inner flats and in the lagoons have not sufficient assistance of that kind, they require special adaptations for keeping their surfaces clean. One of these adaptations is for the colony to be divided into upward-pointing branches, which present very small or no flat areas on which sediment can lodge. Other corals, *Maeandra areolata* for example, has greatly developed cilia, which move the sediment toward the periphery of the colony and cause it to drop off. Some species, *Siderastrea radians* for instance, can stand temporary burial. A. G. Mayer discovered that those corals that can withstand the highest temperatures can endure the longest burial. The capacity to resist the effects of high temperature and that to resist the effects of burial are, therefore, brought into relation, and one seems to be the correlative of the other. According to Mayer, high temperature produces death by asphyxiation, as also does burial.

RELATION OF CORALS TO LIGHT.

Light is another factor that affects corals. Plate 16, figure A, represents the wharf at old Fort Jefferson, Tortugas, Florida. Coral larvae have attached themselves to the peripheral piers and many

thriving colonies have resulted, but the more central piers bear few or no corals. Light is the only factor I have been able to imagine to be the cause of this result, for the water under the middle of the wharf is of the same temperature as that outside and the food supply is the same both under and outside the wharf.

Dana says:

> The range of temperature 85° to 74° F. gives sufficient heat for the development of the greater part of coral reef species; and yet the temperature at the 100-foot plane in the middle Pacific is mostly above 74°. The chief cause of limitation in depth is the diminished light, as pointed out by Prof. T. Fuchs.[1]

Hjort says in his article on "The *Michael Sars* North Atlantic Deep-Sea Expedition:"[2]

> * * * Now, if we calculate the depth to which the rays of the sun penetrate, after passing through the same distance in the water, assuming always that the rays are direct, and that the rate of absorption is the same, we find that the rays will have passed through the same distance to reach a depth of 500 meters in 50° north latitude that they will pass through to reach 650 meters in 33° north latitude, or 300 meters in 67° north latitude.
>
> However, the transparency of the water varies greatly in different regions. If we take the results of previous observations during different expeditions, we may set down the visible depth in the open sea as being, roughly, 50 meters in 33° north latitude, 40 meters in 50° north latitude, and 25 meters at the outside in the Norwegian Sea in 67° north latitude. Taking this into consideration, we find that there will be the same *intensity* from the rectilinear rays—
>
> In 33° north latitude, at about 800 meters' depth.
>
> In 50° north latitude, at about 500 meters' depth.
>
> In 67° north latitude, at about 200 meters' depth. * * *
>
> During the Atlantic cruise of the *Michael Sars* we undertook a series of measurements of the intensity of light with a photometer constructed by Doctor Helland-Hansen; to determine the intensity of the different color rays, Doctor Helland-Hansen made use of panchromatic plates and gelatine color-filters. The observation south and west of the Azores (that is to say, at the southern stations) showed that the rays of light strongly affected the plate at a depth of 100 meters. The red rays were weakest here, while the blue and ultra-violet rays were strongest. At a depth of 500 meters the blue and ultra-violet rays were still distinctly visible, and at a depth of 1,000 meters the ultra-violet rays were yet perceptible. In 1,700 meters, however, there was not the faintest trace of light, even after the plates had been exposed for two hours in broad daylight.

The observations recorded in the foregoing quotation show a distinct decrease in the intensity of the red rays of light at a depth of 100 meters. As the maximum development of the deep-sea fauna off the Hawaiian Islands is between depths of 183 and 732 meters and at temperatures between 10° and 4.5° C., depth, temperature, and intensity of light are correlatives. The deep-sea fauna mostly lives at depths too great for the penetration of the red rays, but, where

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[1] Corals and coral islands, 3d ed., p. 125; see also Vaughan, U. S. Nat. Mus. Bull. 59, p. 46, 1907.

[2] Geographical Journ., vol. 37, pp. 505–506, 1911.

most luxuriant, it is reached by the blue and ultra-violet rays; but many deep-sea species live in utter darkness. In higher latitudes the deep-sea fauna of the Tropics, it seems, may live in shallower water, where the light is stronger than in the deep water nearer the Equator.

At the Tortugas I made experiments on 17 species of shoal-water corals to ascertain their relation to light. The specimens were placed in a live car, specially constructed so as to be entirely dark after shutting a trapdoor. At the end of 14 days one species, *Acropora muricata*, apparently had died, and the specimens of all the other species were pale, the green plant cells in the coral tissues having died or lost their color; at the end of 28 days specimens of *Favia fragum* and *Agaricia purpurea* had died; at the end of 43 days one specimen of *Eusmilia aspera* had died, and most of the polyps of *Oculina diffusa* were dead. The notes at the end of 43 days were kindly made for me by Dr. A. G. Mayer, who put on the rocks, under the landing for the laboratory pump wharf, those specimens that withstood the exclusion of light. About a year later I found seven of them and made notes on them on July 21, 1915. These specimens not only survived being in the dark for 43 days, but before the end of a year were again very nearly or quite normal. The fact that shoal-water corals are not normal in the dark, although they will endure the exclusion of light for a considerable period, and the fact that they are absent on the central piers under Fort Jefferson wharf where the light is weak, while they are abundant on the peripheral piers, is strong evidence in favor of light being one of the ecologic factors determining the locus of species of corals. The commensal green algae, known as Zoanthoxellae, that as a rule are embedded in the tissues of shoal-water corals, set free oxygen which is intimately available for use by the corals, as it is in immediate contact with the animal tissues. Since these plants while in the dark cease to set free oxygen, and the corals under such circumstances are deprived of oxygen from that source, it may be that the poverty of coral growth in dark places is due to the suppression of the activities of these plants.

Notwithstanding the high degree of probability that this inference is correct, additional accurate photometric records at depths from about 37 to 183 meters are necessary before completely convincing results may be obtained.

CAPACITY OF CORALS TO WITHSTAND EXPOSURE IN THE AIR.

As the corals that live in very shoal water may be above water level during low-tide periods, it is of interest to know how long they can endure being out of their natural medium. I made a number

of experiments on the species common in the Tortugas, Florida, to ascertain how long they can live out of the water and found that all can withstand limited exposure in the air, but, of course, none of them can live permanently out of water. Colonies of the same species were placed in both the sun and shade on glass plates; and in both the sun and shade in vessels containing enough sea-water to keep the bases of the colonies wet. The death of colonies exposed to the air naturally depends on the rate of the desiccation of the soft animal tissues. As heat accelerates drying, the specimens in the sun are more quickly killed than those in the shade; and, as both the soft parts and the skeletons of all corals are more or less porous, a colony whose base is immersed in sea water will live longer than one lying on a glass plate. Although not precisely, almost generally, those corals with the most porous skeletons can longest endure being out of the water, for such skeletons dry more slowly than those that are more compact, and, if the bases are wet, they rapidly absorb water through capillarity. Any one of the sixteen species of Tortugas corals used in the experiments will endure half an hour's exposure on a glass plate in the shade without apparent damage; nearly all will stand one hour's exposure under such conditions; while some survived such exposure for four hours. Colonies of a number of species were badly damaged but were not entirely killed after lying for one and a half hours on a glass plate in the sun. Of the species experimented with *Favia fragum*, *Porites porites*, and *Porites astreoides* have the greatest capacity for withstanding exposure in the atmosphere, while that of *Maeandra areolata* and *Siderastrea radians* is almost as great. Usually the species that form the exposed reefs can not withstand being out of the water so long as those that live on the shallow flats behind the reefs. Doctor Mayer made a series of exposure experiments on the corals at Murray Island, Australia, and obtained similar results.

RELATION OF CORALS TO CONCENTRATION OF SALTS IN THE OCEAN.

The following is Dittmar's mean of 77 analyses of sea water:

Cl	55.292
Br	.188
SO_4	7.692
CO_3	.207
Na	30.593
K	1.106
Rb	.....
Ca	1.197
Mg	3.725
Fe, SiO_2, PO_4	———
Fe, NH_4, NO_3	———
Al_2O_3, Fe_2O_3, SiO_2	.....
	100.00

The ratio of the weight of the salts in the sea water to any given weight of water is expressed as parts per thousand and is called the salinity of the water, for instance, a salinity of 36 means that there are 36 pounds of salt in 1,000 pounds of water.

The factors affecting the life of corals, so far considered, are all more or less correlated; for instance, at great depths in the ocean the temperature is low, there is no light, and surface agitation of the sea is not felt. The relative salinity of the ocean differs from these factors in that it is not definitely related to any one of them, except that in the Tropics the surface concentration of sea salts is somewhat greater than that at depths considerably below the surface, and that there the concentration is somewhat greater than that on the surface in higher latitudes. In other words, there is in the surface waters of the Tropics some concentration of salts due to evaporation, but the difference in the salinity of the different parts of the ocean, away from the mouths of great rivers, is not sufficient to affect the life of corals. Notwithstanding these facts, it is important to know the maximum and minimum salinities that corals can endure.

The average salinity of the Tortugas water according to Dole is 36.01. Of the 17 species of Tortugas corals kept in a tank of water with a salinity of 18.28 for 24 hours, all were damaged or killed except *Maeandra areolata*, *Siderastrea radians*, and *Porites astreoides*; but no specimen of 16 species showed any evidence of harm after remaining 48 hours in water of a salinity of 27.87. Apparently corals would not be hurt if the salinity of the ocean were reduced to about 80 per cent of its present salinity. Mayer obtained similar results in his work on the corals of Murray Island, Australia.

Although I did not experiment with concentrated sea water, the studies made by Goldfarb and others on the effect of concentrated and diluted sea water on regeneration in hydroids and in the jelly-fish *Cassiopea* are here pertinent. The combined results of the experiments are in accord with the deductions made by oceanographers and geologists from other data, viz, the ocean is becoming more salt, and it appears that marine organisms are now living in an environment which is considerably below the optimum condition for their existence.

HOW CORALS CATCH THEIR FOOD AND WHAT THEY EAT.

I made no more interesting experiments on corals than those to discover how they catch their food and what they eat. Although nearly all the species abundant in the Tortugas were used in making the experiments, one species, *Maeandra areolata*, was studied more than any other. It was fascinating to bring a colony with the animals composing it entirely retracted, as in plate 22, and induce it to

expand as in the colony represented by plate 17. This expansion was instigated by placing the colony in a vessel in a shady (not really dark) place, where it would not be shaken, and then feeding it with a little beef juice through a pipette, or by giving it a small bit of meat, usually crab flesh or fish. The tentacles at the end of the colony to which the food was offered would begin to appear, and the stimulus was transmitted to other members of the colony, until after a short time the surface of the specimen would remind one of a beautiful open flower. This condition of a coral colony seems to signify that it is hungry and is ready to capture food.

Special mechanisms of corals for catching food are greatly developed. They comprise, as follows: (1) The nematocysts, the stinging cells and their coiled threads, which occur in the ectoderm, the outer layer of the soft tissue and its modifications, on the tentacles, the oral disk (between the tentacles and the mouth), the sides of the polyps, and also on the mesenterial filaments. (2) The entire ectodermal surface is ciliate, the cilia in response to certain stimuli beating toward the oral apertures; in response to others, beating toward the periphery. (3) The outer surface secretes mucus in which particles may be embedded, the mucus moving under the influence of the beat of the cilia toward the oral apertures or toward the periphery, according to the nature of the response to the stimulation. (4) The tentacles are active and effective in capturing food. (5) The mesenterial filaments, which in many species of corals can be extruded through the column walls, in some instances capture food.

FIG. 1.—NEMATOCYSTS OF MAEANDRA AREOLATA (LINNAEUS), VERY HIGHLY MAGNIFIED. AFTER L. AGASSIZ FROM DRAWINGS BY BURKHARDT AND D. SONREL.

Many different kinds of food were offered corals, but they took only animal food—they are entirely carnivorous. The following experiment was tried many times: A piece of diatom mat was placed on one side of the oral disk and a piece of crab meat on the other. Invariably the crab meat was seized and swallowed; while the diatoms induced no reaction except ultimately to be removed from the surface. No kind of purely vegetable food was taken by any one of the numerous species investigated. However, pieces of plants coated with small animals or soaked in meat juice will be swallowed, and later the vegetal matter ejected.

One of the experiments that I found particularly fascinating was to drop living specimens of the small crustacea, known as copepods, within the expanded tentacles of *Maeandra areolata*. These little animals because of the quickness of their motion are popularly called water fleas, but they did not move swiftly enough to escape the lightning-like dart of the coral's tentacles and nematocysts—they were all caught and swallowed.

Plate 18 illustrates *Maeandra areolata* during the swallowing and digestion of rather large pieces of food. The usual behavior of corals while they are gorged with food and after hunger is entirely satisfied, is to retract their tentacles and other distensible organs. Furthermore, after complete satiation, the direction of ciliary motion reverses and particles of food dropped on the surface will be moved toward the periphery of the coral in a manner similar to that in which the surface is cleaned of nonnutrient particles.

The distribution of corals according to depth is dependent upon the distribution of small floating and swimming animals which entirely supply their food. Should the quantity of such food decrease with increasing depth, such decrease would limit the downward extent of the shoal-water fauna, but as I do not know of any quantitative estimates of the amount of such food above and below 46 meters in coral reef areas, there is no basis for a positive opinion.

REARING CORAL LARVAE.

The rearing of coral larvae is important because only by knowing the duration the free-swimming planulae stage can the possibilities of the distribution of corals by marine currents be understood; and, it is obvious that, in order to ascertain precisely how rapidly corals grow, the life of the same colony should be followed from the time the planula to which it owes its existence first settled. Two of the methods of obtaining and rearing planulae will be briefly described.

Colonies extruding planulae were brought into the laboratory and kept in glass vessels of sufficient size to furnish an adequate supply of water, which should be changed rather frequently. The planulae were removed from the vessels containing the parent colony to a

culture jar, on the bottom of which was a terra-cotta disk having a central perforation that fitted over the head of an iron stake.

The disks[1] had a diameter of 8 inches and were placed in jars, the inside diameter of which was about 8¼ inches, and the depth about 8½ inches. After the bottom of a jar had been covered with the cleanest sand obtainable, a disk was placed in the jar, and the central perforation and the space between the periphery of the disk and the sides of the jar were filled with sand to the level of the upper surface of the disk. Filling these spaces is necessary, as the planulae tend to settle in depressions. After this preparation, pure sea water was gently poured in through a funnel until the jar was nearly full. Then the extruded planulae were taken with a pipette from the vessel containing the parent colony and placed in the culture jar prepared for their reception.

To get the best results, the water in the culture jar should be changed at least once a day. This may be done by several devices. In order not to draw off the planulae, which are very small, a bag of fine-mesh bolting cloth must be affixed to any tube used in withdrawing the stale water. One method was to siphon off the stale water with a rubber tube, the end of the tube inserted into the culture jar having been drawn over one end of a glass tube, the other end of which was enveloped in a bolting-cloth bag. The table on which the culture jars stood was provided with a gutter into which the water drawn off was discharged and was ultimately carried outside the building by a pipe through the floor. After a jar had been emptied to within an inch of the disk it was refilled with fresh sea water. This method causes a change in the level of the water, and the pouring stirs up the unattached planulæ. A second method was to withdraw the old water by a glass siphon resting on the upper edge of the jar, the siphon having been rendered nonemptying by having its outer end bent upward. Fresh seawater was added by a siphon extending to the bottom of the culture jar from a supply jar placed at a higher level. By this method a constant level was maintained in the culture jars, the old water was drawn off from the top, while the new water was added at the bottom. This method is illustrated by pl. 19, figure A.

Two other devices were used for changing the water—one of them replenished it without, the other with change of level, but they will not be described here. All four of the methods tried were successful, and the preference between them was not determined. Pure water is necessary and occasional stirring of unattached planulae may be beneficial. It is imperative that the sea water used in these cultures be

[1] Vaughan, Carnegie Institution of Washington Year Book No. 9, 1911, pp. 141, 142.

normally pure, that is, not contaminated by refuse or other abnormal impuritites.

It is relatively easy to get large numbers of planulae to attach themselves to disks by using the culture methods above described.

DISTRIBUTION OF CORALS BY MARINE CURRENTS.

It has already been stated that because of its bearing on the possibility of the distribution of coral species by oceanic currents, it is highly important to know the duration of the free-swimming larval stage. Observations were made on four species. The range was from 2 to 23 days. Should an ocean current have a velocity of 3 knots per hour, in 23 days planulae might be carried 1,656 knots; at 2 knots per hour, 1,104 knots; at 1 knot per hour, 552 knots. It is known that every species of shoal water coral in the Bermudas is found in Florida and the West Indies; while not only is the Hawaiian fauna Indo-Pacific in its affinities, but several of the species (at least four) also occur on the east coast of Africa or in the Red Sea, and I seriously doubt any part of the Hawaiian fauna being peculiar to those islands. The clue to the cause of the wide distribution of living coral species is given by the possibly long duration of the free-swimming larval stage. It should be mentioned here that numerous instances of the transport of coral colonies attached to floating pumice or to driftwood are on record, but it seems to me that the transportation of larval corals is more important in the distribution of corals by ocean currents than the transportation of attached colonies.

RATE OF GROWTH OF CORALS.

The growth-rate of corals was studied on colonies developed from planulae that were reared in the laboratory according to methods already described and then planted in the sea (pl. 21), and on colonies from planulae naturally attached but known to have settled in a certain season; on colonies fastened with Portland cement to terra cotta or reinforced concrete disks and then fixed on the heads of iron stakes driven into the sea bottom (pls. 22–25); and on colonies naturally living in the ocean.

Two methods were used for rearing to subsequent stages the larvae that settled in the laboratory culture. One was to fasten the disks bearing the young polyps to the bottom of a floating live car; the other was to plant the disks directly on stakes. Both methods succeeded. Plate 20, figures A and B, illustrate the method of planting in a floating live car; Plate 19, figure B, the apparatus for planting on iron stakes. A long iron bar, with a cap on the lower end

fitting the head of the stake, was used for driving the stakes below water level. The disk was made fast by an iron pin through a hole in the head of the stake.

In the Tortugas, colonies that were attached to disks with hydraulic cement were planted (a) off the northwest face of Fort Jefferson moat wall; (b) on the reef off Loggerhead Key. Colonies naturally attached were studied at the following places: (a) In Fort Jefferson moat; (b) on piers of the Fort Jefferson wharf; (c) on the outside of the northwest face of the Jefferson moat wall; (d) on the reef off the northwest face of Loggerhead Key. The different places at which corals were planted and those at which observations on naturally attached colonies were made are illustrated by plate 19, figures A, B, C, and plate 20, figures A, B.

Observations and experiments were made in the Bahamas on the leeward side of the north end of a small island, known as Golding Cay, which is on the east side of Andros Island at the mouth of South Bight. The specimens included (a) those cemented to tiles and planted; (b) those living naturally attached.

The colonies in the Tortugas were measured and photographed once a year; while two years elapsed between the first and second measurements of the colonies in the Bahamas. The measurements and photographic exposures of the colonies attached to disks were made while the colonies were out of the water. It was shown on page 205 of this article that corals may live out of the water a much longer time than is needed for such operations.

The following table gives the size of colonies of *Favia fragum* according to age (pl. 21). The average annual increment is indicated by the number preceded by the + sign below that for the average size. The average most rapid growth is during the first year, after which it declines, but should a specimen not attain an average size during the first year, it may grow rapidly during succeeding years until it catches up to the average. Compare specimens Nos. 1 and 6 of the table.

Size of colonies of Favia fragum—averages according to age.

No.	1 year old.		2 years old.		3 years old.		4 years old.		5 years old.	
	Diameter.	Height.	Diameter.	Height.	Diameter.	Height.	Diameter.	Height.	Diameter.	Height.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	11	4	27	6	30	11	30.5	11	....	....
2	13.5	4	22.5	7	25	10	26	11	....	....
3	10	6	31	11	33.5	12	34	13	....	....
4	10	5	20	11	22.5	14	30	16	....	....
5	12	4.4	31	11	34	14	41	17	....	....
6	6.5	5	17.5	8	25.5	13	32	14	38	20
7[1]	10	6	....	10.5	....	14.5	....	16	....	22
8[1]	13	3	....	9	....	....	....	....	....	....
9	9	2.5	19	7	20	9	21	11	....	15
10	10	2.5	17	10	20	....	20	10	33	12.5
11	5	2.5	11	4	....	....	....	....	....	....
12	....	....	....	....	36	....	31	....	34.5	....
13	9	....	26.5	8	33	11	....	....	....	....
14	13	....	20	6	....	....	....	....	....	....
15	14	....	23.5	9	27.5	12	31	13	30	10
16	11	....	25	9	27.5	11	32	14	30	16
17	10	....	18	9	....	....	....	....	....	....
18	9	....	11.5	8	17	10	....	....	....	....
19	10	....	16.5	5	19	6	....	....	....	....
20	12.5	....	18	....	17	....	....	....	....	....
21	15.5	....	15	5	....	....	....	....	....	....
22	6.5	....	13	....	....	....	....	....	....	....
23	9	....	16.5	10	23	11	....	....	....	....
24	12	....	24	....	27.5	12	26	14	....	....
25	9	....	21.5	9	25	12	27	15	....	....
26	10	....	13	....	19.5	....	29	....	....	....
27	16.5	....	22.5	6	23	....	....	....	....	....
28	12	....	19	7	22	....	29.5	....	29.5	....
29	17	....	23	7	34.5	....	35	....	33	18
30	11	....	13	3	....	....	....	....	....	....
Average	11.03	4	21.01 (±5.16)	7.9 (±2.30)	23.18 (±5.13)	11.49 (±3.5)	30.13 (±4.97)	13.77 (±2.31)	34.71 (±4.58)	17.71 (±3.46)

[1] As Nos. 7 and 8 fused, separate measurements of the diameters became impracticable.

Favia fragum is a species that never attains a large size, between 60 and 75 millimeters being about the usual maximum diameter.

The size of colonies of *Porites astreoides*, according to age is given in the following table:

Size of colonies of Porites astreoides—averages according to age.

No.	1 year old.		2 years old.		3 years old.		4 years old.		5 years old.	
	Diameter.	Height.	Diameter.	Height.	Diameter.	Height.	Diameter.	Height.	Diameter.	Height.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	22.25	....	25	12	42.5	30	50.5	30	75	54.4
2	14.75	....	35	....	37	....	41.5	....	54.25	....
3	9	2 or 3	33	6	30	10	45.75	18	64	21
4	15.75	3	30.5	10	53.5	12	62.5	23	68.75	31
5	16.25	....	24.25	....	41	....	54	....	66.75	....
6	10.5	....	31.5	....	38	....	41.75	....	45.5	....
7	16.5	....	33	....	45	....	50.5	....	65.25	....
8	10.75	....	24.5	....	25	10	28	17	33.5	21
9	6.25	....	14.5	....	26.5	7	33.5	12.5	63	21
10	8.5	....	18	....	34.5	5	....	9	41	....
11	7.75	....	18.5	....	46	....	....	....	....	....
12	15.5	....	42	7	52.50	8	62.5	13	75.5	19
13	10.75	....	21	....	35.5	....	51.75	....	62.5	....
14	13.75	....	30	....	39.5	....	44.5	....	55.5	....
15	....	....	....	....	....	....	47	....	64.5	....
Average	12.36	3	28.41 (+10.04)	8.75 (+5.75)	30.[illegible] (+5.46)	10.28 (+1.53)	51.[illegible] (+12.[illegible])	15.92 (+5.64)	61.21 (+11.00)	27.75 (+8.83)

Tables giving the summaries of my work on the growth-rate of the Floridian and Bahaman corals have been published in the papers cited in the footnote.[1] The growth-rate of 25 species was investigated, and a total of some thousands of measurements were made. Of course, as no such mass of data can be presented in this place, a few general statements must suffice.

The size of the colonies of all species of corals seems limited, but some attain large dimensions, 2 to 3 meters or even more in diameter, and nearly as much in height, while other species are adult when a diameter of 35 to [illegible] millimeters has been reached. The records of *Favia fragum* and *Maeandra areolata* illustrate relatively rapid growth for the first two to four years, after which it decreases. Other species, for instance, *Orbicella annularis* and *Maeandra strigosa*, are not so limited in size. Ramose corals increase in dimensions more rapidly than massive species; while of the former, the growth-rate of species with perforate, loose-textured skeletons is more rapid than that of those with dense skeletons. In general the more massive and the denser the corallum, the slower the growth; while the more ramose and the more porous the skeleton, the more rapid theg rowth.

[1] Vaughan, T. W., The geologic significance of the growth-rate of the Floridian and Bahaman shoal-water corals: Washington Acad. Sci. Jour., vol. 5, pp. 591–600, 1915; On Recent Madreporaria of Florida, the Bahamas, and the West Indies, and on collections from Murray Island, Australia: Carnegie Institution of Washington Yearbook No. 14, pp. 220–231, 1916.

Some species of *Acropora* under favorable conditions on an average grow in height from 40 to 45 millimeters per year.

There is no average growth rate for corals generally speaking, because growth-rate varies from species to species and varies for the same species according to local environmental conditions. A colony of a species of reef coral in a lagoon, if protected from sediment, may grow more rapidly than a colony of the same species does on the reef. The limitation of reef corals so largely to the outer edges of platforms, is determined primarily by the freedom of the water from silt and by the more uniform temperature.

In order to estimate the rate at which a reef will grow, the upward growth-rate of the true reef-forming species must be taken. The upward growth-rate of *Orbicella annularis*, the principal builder of the Pleistocene and living reefs in Florida and the West Indies, is from 5 to 7 millimeters per year, according to station. At 6 millimeters per year, it would form a reef 150 feet (=46 meters) thick in 7,620 years; at 7 millimeters per year it would build the same thickness of rock in 6,531 years. *Acropora palmata*, which grows more rapidly might build a similar thickness in 1,800 years. The growth of corals in the Pacific appears to be more rapid and according to Stanley Gardiner they might build a reef 150 feet thick in 1,000 years.

Growth-rate is one of the important factors in the battle between corals and some of their natural enemies. For instance, if corals grow less rapidly than sediment is being deposited on the bottom, although other conditions may be favorable for their life, they will surely be killed by smothering. In the competition between attached and incrusting organisms, growth-rate is one of the most important factors in determining which shall survive. Corals, as my experiments showed, may grow with great rapidity in locations where they cannot survive, or are only poorly represented, because the habitat is suited to other organisms of a more rapid rate of growth. Among these inimical organisms are various marine algae, including the calcareous *Halimeda* and incrusting nullipores; other such organisms are sponges, tunicates, Bryozoa, and pelecypods.

A study of the growth-rate of corals has an interest not only in understanding the rate at which they may form rock, but also in understanding their struggle for life against enemies, both organic and inorganic.

SUMMARY OF STATEMENTS ON CORALS.

The preceding pages show that in the ocean there are:

1. The deep-sea corals at depths of 150 meters or more, where the light is weak or where there is perpetual darkness, and where the temperature ranges from 1° to 15.6° C., although they thrive best

where the temperature is between 4.5° and 10° C.; these are mostly cup-corals or delicately branching forms. It seems that this fauna lives in shallower water in higher latitudes than it does in the Tropics.

2. Between depths of 46 and 74 meters in the Tropics, there is a moderately distinctive fauna that is more closely related to the shallow-water than to the deep-water fauna.

3. In the shallow waters of the warm parts of the tropical oceans there is another fauna, the one that forms coral reefs, and its local adaptations to the character of motion of the water, sediment, and other factors have been described. The conditions necessary for the vigorous growth of reef-forming corals are as follows: (a) Depth of water, maximum, about 46 meters (25 fathoms); (b) bottom firm or rocky, without silty deposits; (c) water circulating, at times strongly agitated; (d) an abundant supply of small animal plankton; (e) strong light; (f) temperature, annual minimum not below 18° C.; minimum average temperature for the coldest month in the year not lower than about 22° C.; (g) salinity between about 27 and about 38 parts per thousand.

4. According to conservative estimates, reef corals can build a reef 46 meters (150 feet) thick within a period ranging from 1,800 years to 7,500 years; but, in places, a reef of such a thickness might be formed within 1,000 years, according to Gardiner.

THE FORMATION OF CORAL REEFS.

DEFINITION OF THE TERM "CORAL REEF."

The preceding pages are devoted to a general account of corals and the conditions under which they live, and no definition of "coral reef" has as yet been given, although the term has been used. In order to give some idea of a coral reef several illustrations are introduced. Plate 26, figures A, B, represent the reef off the west face of Loggerhead Key, Tortugas, Florida, as exposed at very low tide on June 6, 1910. The heads projecting above the water are *Orbicella annularis*, the principal reef-building coral of the Floridian and West Indian region; the fanshaped objects are the alcyonarian coral, *Gorgonia flabellum;* while the rod or whip like objects are other Alcyonaria that belong mostly to the genus *Plexaura.* Plate 26, figure C, is from an undersea photograph taken at Carysfort Reef, south of Miami, Florida. This illustration shows the beautiful, waving gorgonians, especially the fan coral, and large heads of *Orbicella annularis*, as well as some other stony corals; but it does not show the highly colored fishes that dart in and out among the coral heads and constitute one of the enchanting sights to be seen on coral

reefs. Plates 27 and 28 are reproductions of two of Saville-Kent's photographic illustrations of the Great Barrier Reef of Australia. These three plates illustrate true coral reefs, which in my opinion should be defined as follows: Coral reefs are ridges or mounds of limestone, the upper surfaces of which lie, or lay at the time of their formation, near the level of the sea, and are predominantly composed of calcium carbonate secreted by organisms, of which the most important are corals.[1]

The composition of what I consider true coral reefs is very complex. The main framework of the reef is formed by coral heads and stout coral branches, while the interspaces are filled by small corals, and the skeletons of other organisms, some of which in the course of time are more or less broken up by the waves. In many cases it is difficult to decide whether or no to apply the designation "coral reef" to richly coralliferous deposits that are obviously bedded. However, it seems to me that it should be applied wherever corals of reef facies seem sufficiently abundant to have formed appreciable rugosities on the sea bottom, although the deposits are bedded. Reefs predominantly composed of the remains of calcareous algae should be designated "nullipore" or "Lithothamnion reefs." But, where the proportion of these organisms to corals is so nearly the same that only exact computation will decide between the two, such a reef may be designated "coral."

SOME KINDS OF LIMESTONE THAT HAVE BEEN CONFUSED WITH CORAL-REEF ROCK.

To many it may seem superfluous in a definition of coral reefs to say that the remains of corals should be an important constituent of the rock; but the term "coral rock" or "coral-reef rock" has been repeatedly applied to limestone with the making of which corals have had either nothing, or practically nothing, to do. An excellent instance of such a popular, and until recently scientific, misconception is supplied by the Bahama Islands.

According to Alexander Agassiz the Bahamas are composed of wind-blown coral-sand. The sand composing the ridges in the Bahamas, at least those I have seen on New Providence and Andros Islands, has certainly been wind-blown. Plate 30 illustrates an exposure along East Street in Nassau, and plate 29, figure B, represents the face of a small cliff at the south end of Morgan Bluff, Andros Island, both in the Bahamas; while figure A of plate 29 is from a photograph of a section of a sand dune at Cape Henry, Virginia. These illustrations show the essential similarity of the

[1] Vaughan, T. W., Physical conditions under which Paleozoic coral reefs were formed: Bull. Geol. Soc. America, vol. 22, p. 238, 1911.

arrangement of the material in the Bahamian ridges and of that in a sand dune at Cape Henry. The sand at Cape Henry is siliceous (quartz) sand; while that composing the hills and ridges in the Bahamas is calcareous, almost pure, more than 99 per cent, carbonate of lime. Limestone composed of grains similar to the grains in the wind-formed hills underlies the surface of the low, flat areas in the Bahamas, but its grains have not been wind-blown. They were formed in the sea and were later uplifted so that they now stand above sea-level. As this kind of limestone has been improperly called coral rock, a short account of the mode of its formation will be given.

A close inspection of a piece of this rock, even with the naked eye, reveals that it is composed of minute balls and ovoid or ellipsoid bodies, from 0.2 to about 1 millimeter in diameter, set into a cementing groundmass. Plate 31, figure A, illustrates the surface of a specimen natural size, and figure B represents a part of the same surface enlarged 10 times. Because the ball-like bodies composing the rock give it an appearance similar to fish roe, it is known as oolite, which means egg rock. Plate 32, figure 1 illustrates a thin slice of a single grain magnified 100 times. It is entirely obvious that these bodies are composed of concentric coats, and that they were formed by some process that caused outer coats to be successively laid down on the inner ones. It was stated in the preceding paragraph that this rock contains more than 99 per cent calcium carbonate, and that the egglike granules originated in the sea. How was the carbonate of lime taken out of the sea?

Recent investigations have very clearly shown that there is in the shallow waters of the tropical and subtropical parts of the ocean as much carbonate of lime in solution as it is possible for the water to hold—in other words, the water is saturated with carbonate of lime. It is therefore clear that any agency that will reduce the capacity of such water already saturated to hold calcium carbonate in solution will cause that substance to be precipitated. The principal solvent of calcium carbonate in sea water is carbon dioxide (CO_2), popularly known as carbonic-acid gas, and the reduction of the amount of it in the sea water will produce precipitation. Raising the temperature of the water, whether naturally or artificially, reduces its capacity to hold CO_2, and agitation, if there is too little CO_2 in the air, will hasten the process. Evaporation, leading to a greater concentration of salts in the water, will also cause precipitation of calcium carbonate.

Besides the inorganic agencies mentioned, there are organic agencies that cause the precipitation of calcium carbonate in the sea. It has been known for a long time that the addition of a strong alkali, such as ammonia, to sea water will produce precipitation of

carbonate of lime. There are several kinds of bacteria that cause the formation of ammonia in the ocean. One of these kinds is known as denitrifying bacteria, because they break up nitrate salts in the sea, converting nitrates into nitrites and these into ammonia, and they are to a considerable degree responsible for the limited development of green plants in tropical seas, as they rob such plants of an important part of their food. G. H. Drew found as many as 160,000,000 of these bacteria in 1 cubic centimeter of mud off the west side of Andros Island, Bahamas, opposite the mouth of South Bight. A figure (reproduced from one by Kellerman) is here given of this very minute organism, which is known as *Pseudomonas calcis* (Drew) Kellerman. Any other bacteria that will evolve ammonia and green plants by taking CO_2 from the water will also cause the precipitation of calcium carbonate. In such areas as the shoal waters on the lee sides of the islands and in the lagoons in the Bahamas, where all of the agencies mentioned are cooperating to bring about the precipitation of calcium carbonate, it is not at present possible to estimate how much of the effect is attributable to each.

FIG. 1.—*Pseudomonas calcis* (DREW) KELLERMAN. GREATLY ENLARGED. AFTER KELLERMAN.

The material when first precipitated is very finely divided, and may form very minute needles or small balls of the mineral known as aragonite. On plate 32, figure 3 illustrates some of the aragonite needles, magnified 840 times, and figure 2 illustrates some balls taken from the mud, both out of the same sample, from the west side of Andros Island, Bahamas.

Oolite grains of calcium carbonate may be produced artificially, either by means of cultures of bacteria that evolve ammonia or by adding ammonia to sea water. An illustration of a thin section of an oolite grain from Great Salt Lake is given on plate 32, figure 4; the figures on plate 33 illustrate artificially formed grains. As the very fine concentric banding of the Bahamian oolite grains has not yet been reproduced in the laboratory, there are still some features of these grains that need more investigation.

Some investigators of the origin of oolite grains have contended that they are formed by filamentous algae, because borings apparently made by such organisms were found in the grains. Algae of this kind bore into nearly all carbonate of lime structures exposed to their attacks; they even bore into coral skeletons up to the limits of the soft animal tissues. On plate 34, figure 1 illustrates some of

these algae obtained by decalcifying a specimen of the coral *Orbicella cavernosa;* figure 2 shows the algae in place in the skeleton of *Orbicella annularis;* while plate 32, figure 1, represents an oolite grain in which there are no algae, but I am confident I could have found an oolite grain with algae in it.

Some of the oolite of the Bahamas remains as it was bedded in the sea, except that it has risen or fallen with the movements of the crust of the earth, while other rock has been broken up and has supplied grains to be heaped into dunes by the winds.

Although the Bahamas have been called coral islands, they are not coral islands, for they are mostly composed of oolite formed from calcium carbonate organically or inorganically precipitated in the ocean, some of which has been broken up and blown about by the wind. There are coral reefs in the Bahamas, and they are exceedingly dangerous to navigation, but they occupy an area probably between only one three-thousandth and one six-thousandth as large as that underlain by the oolitic limestone.

Oolitic limestone similar to that so widespread in the Bahamas also occurs in southern Florida, where the area underlain by it is many times greater than that occupied by coral-reef rock; and the Bermudas, popularly thought to be "coral islands," according to Verrill, are mostly composed of shell sand and *not coral sand.* Besides these two kinds of limestone, rock predominantly composed of the tests of Foraminifera and Bryozoa should be definitely excluded from the category of "coral rock." The study of the formation and classification of limestones is fascinating, and I should like to pay much more attention to it than is practicable in the present brief review of a large subject.

I also regret being obliged to pass over, almost without mention, other organisms than stony corals that contribute material incorporated in reefs. There are the discoid *Orbitolites* and flat-coiled *Orbiculina*, Foraminifera so abundant in Florida and the West Indies, the stellate *Tinoporus baculatus* of Australia and other species that live on the Pacific reefs, and *Polytrema mineaceum*, ubiquitous on coral reefs as blood red, reticulated incrustations on dead corals and shells. Alcyonaria are important contributors to bottom deposits in places, although, in my opinion, no quantitative evaluation of their work has yet been accomplished; and echinoids add their tests and spines to the remains of the members of the other groups. Coralline algae vie with stony corals in relative importance, in some places one group, in other places the other holding first rank as reef-builder, and at least in many places in the Pacific form incrustations just landward of the sea face of barriers. An account of the charms and dangers or discomforts of reefs must be abbreviated practically to its suppression. I will only say beware of the long, waving, pointed

spines of the sea urchin, *Diadema setosum* (now called *Centrechinus setosus*); look warily into crevices, and step carefully into pools, otherwise sore feet, legs, arms, and hands for days or weeks to come may be the penalty!

GEOGRAPHIC DISTRIBUTION OF CORAL REEFS.

Having given a definition of "coral reef" and having eliminated from the category of coral reef and coral rock, limestones whose formation is independent of the activities of corals, a few words will be devoted to stating where coral reefs occur. They are found in those parts of the ocean where the conditions summarized on page 215 of this article prevail. As the proper conditions of depth, salinity, and purity of water, intensity of light, and character of bottom, are widespread in the ocean, the temperature factor is critical in restricting coral reefs to certain areas in tropical and subtropical seas. Coral reefs thrive only where the average temperature of the coldest month of the year does not fall below about 21° C. (70° F.), and where the usual temperature is between 25° and 30° C. (77° to 86° F.).[1] A well-known oceanographic fact is that the waters along the western shores of continents are colder than those on the eastern sides. The great living coral reefs are therefore in the tropical western Pacific Ocean, around the tropical islands of the mid-Pacific, in the Indian Ocean and the Red Sea, and in the tropical and subtropical western Atlantic Ocean. Reef corals are weakly developed on the Pacific side of Central America and Mexico and on the Atlantic coast of Africa.

Some features of the Atlantic (Caribbean and Floridian) reefs will now be compared with those of the Indo-pacific reefs. There are at present two great biogeographic divisions of reef-coral faunas: one is the Atlantic, the other is the Indo-Pacific, separated from each other by the land area of Central America. In their ecologic relations the reef corals of the two regions are identical, but there are important systematic differences, and the Pacific corals are more luxuriant in growth and more numerous in species than the Atlantic. That Pacific corals appear to grow more rapidly than those in the Gulf of Mexico and the West Indies was pointed out on page 214 of this article. The number of species on a section of an Indo-Pacific reef usually ranges between about 55 and something over 70. Von Marenzeller records 71 species from the Red Sea; Bedot lists 74 species and 5 varieties from Amboina, but I believe 4 of his specific names are synonyms, leaving 70 valid species. I have identified 63 species in Mayer's collection from Murray Island, Australia, and 51

[1] For detailed information on this subject see as follows: Vaughan, T. W., Temperature of the Florida coral reef tract: Carnegie Inst. Washington Pub. 213, pp. 319–339, 1917; and Mayer, A. G., in his "Ecology of the Murray Island coral reef," ibid., pp. 1–48, pls. 1–19, gives the temperature records for the Murray Island reef for the period while he was there.

species in Wood Jones's collection from Cocos-Keeling Islands, but it is known that a few more species occur in the latter group of islands. I collected at the Tortugas, Florida, about 32 species, but this does not represent all the species in the Floridian reef fauna, and about 26 species at Cocoanut Point, Andros Island, Bahamas, but additional species were collected on the reefs near the mouth of South Bight, and other species are known to occur in the Bahamas. The total number of Bahamian shoal-water species is about 35. Therefore, on a segment of a rich reef in the Indo-Pacific there are about twice as many, or a few more than twice as many, species as there are on a similar segment of a West Indian or Floridian reef. It would require too much space to discuss the systematic differences between Indo-Pacific and Atlantic faunas here, but it may be stated that the following are the names of some of the Indo-Pacific genera not known living in the Atlantic, viz: *Pocillopora**, *Seriatopora*, *Stylophora**, *Euphyllia**, *Cyphastrea*, *Leptastrea*, *Galaxea**, *Antillea**, *Favites**, *Trachyphyllia*, *Hydnophora**, *Leptoria**, *Symphyllia*, *Fungia*, *Herpetolitha*, *Polyphyllia*, *Halomitra*, *Podobacia*, *Pachyseris*, *Pavona**, *Leptoseris**, *Haloseris**, *Coeloseris*, *Psammocora*, *Diploastrea**, *Astreopora**, *Turbinaria*, *Montipora*, and *Goniopora**, but those whose names are marked by an asterisk (*) occur in geologic formations of Oligocene age in the southern United States, the West Indies, and Central America, and some of them range upward into the Miocene. This list might be greatly increased, but it will impress the reader that many genera now living in the Indo-Pacific region, but absent in the living Atlantic fauna, are represented in the Tertiary geologic formations on the Atlantic side of the North American Continent. Of the Atlantic genera not known to be living in the Indo-Pacific region there are *Stephanocoenia*, *Eusmilia*, *Meandrina*, *Dendrogyra*, and *Manicina*, and some other genera are probably not represented there, while the species of other genera that are represented in both the Atlantic and the Indo-Pacific are not closely related.

That the Indo-Pacific and Atlantic faunas were not always so distinct as they now are has been indicated in the foregoing paragraph. Geologic investigations have revealed that during later Eocene, all or most of Oligocene, and a part of early Miocene time, the two oceans were connected across Central America, and that the same faunas occurred in both oceans. In places the older Tertiary faunas in the West Indies contained as many species as are at present found on an Indo-Pacific reef. For instance, about 69 species are reported from the Oligocene of the island of Antigua, where I personally collected 60 species. In middle and later Miocene time the Atlantic and Pacific became separated by a land bridge from South

to North America, and by Pliocene time the corals of distinctive Indo-Pacific facies had become extinct on the Atlantic side, so that the Pliocene coral fauna of Florida is purely Atlantic in its affinities. After the differentiation of the Atlantic from the Indo-Pacific fauna it seems that there was a short connection somewhere that permitted the Atlantic fauna to extend on the Pacific side of America up to the head of the Gulf of California.

THEORIES OF THE FORMATION OF CORAL REEFS.

Three kinds of coral reefs are generally recognized, viz: (1) fringing or shore reefs which occur along the shore; (2) barrier reefs which occur at variable distances offshore and have lagoons from 1 or 2 to as much as 30 or even 40 fathoms in depth between them and the shore line; (3) atolls, which are ringlike and inclose lagoons above whose surface no land masses of importance protrude.

As the literature on coral reefs is so enormous that a detailed review of it in this paper is impossible, coral reef theories will be here classified into three general categories, with a subordinate division of the third.

1. The first theory is that of Darwin and Dana. According to these authors corals first form a fringing reef along the shore of the gently sloping bottom of a subsiding land area; the reef grows upward at such a rate that its top remains near the surface of the water and through retreat of the shore it is converted into a barrier. Continued subsidence, where the inclosed land area is an island, may result in the production of an atoll circumscribing a lagoon without any land mass projecting above the water level. But the Darwinian hypothesis involves more than mere subsidence and the conversion of a fringing into a barrier reef, for it also attempts to account for extensive submarine platforms by assuming that they have been built upon *sloping* basements through agencies dependent on the presence of reefs.

The accompanying two figures (p. 223) are reproductions of Darwin's original illustrations; while the third (p. 224) is J. B. Jukes's diagrammatic cross section of the Great Barrier Reef of Australia.

2. The next general theory of coral reef formation was originated by Carl Semper,[1] who, in 1863, after studies in the Pelew Islands and noticing evidence of uplift there, announced the opinion that atolls could be formed in areas of stability, or even uplift, by the solution of the interior of limestone masses, and that erosion by currents and wave cutting could develop channels behind fringing reefs, and in that way transform a fringing into a barrier reef.

[1] Semper, Carl, Reisebericht: Zeitschr. für wiss. Zool., vol. 13, pp. 563–569, 1863.

Murray[1] in 1880 published the following summary of his opinions on the formation of coral reefs:

That when coral plantations build up from submarine banks they assume an atoll form, owing to the more abundant supply of food to the outer margin,

FIG. 6.—COPY OF DARWIN'S FIGURE ILLUSTRATING CONVERSION OF A FRINGING INTO A BARRIER REEF, ACCORDING TO HIS HYPOTHESIS. *AA.* OUTER EDGE OF THE REEF AT THE LEVEL OF THE SEA. *BB.* SHORES OF THE ISLAND. *A'A'.* OUTER EDGE OF THE REEF, AFTER ITS UPWARD GROWTH DURING A PERIOD OF SUBSIDENCE. *CC.* THE LAGOON-CHANNEL BETWEEN THE REEF AND THE SHORES OF THE NOW ENCIRCLED LAND. *B'B'.* THE SHORES OF THE ENCIRCLED LAND.

N. B.—In this and the following cut the subsidence of the land could only be represented by an apparent rise in the level of the sea.

and the removal of dead coral rock from the interior portion by currents and by the action of the carbonic-acid gas dissolved in sea water.

That the barrier reefs have been built out from the shore on a foundation of volcanic débris or on a talus of coral blocks, coral sediment, and pelagic shells, and the lagoon channel is formed in the same way as a lagoon.

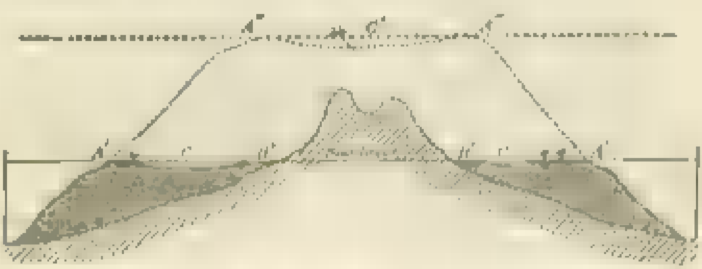


FIG. 7.—COPY OF DARWIN'S FIGURE ILLUSTRATING CONVERSION OF A BARRIER REEF INTO AN ATOLL, ACCORDING TO HIS HYPOTHESIS. *A'A'.* OUTER EDGES OF THE BARRIER REEF AT THE LEVEL OF THE SEA. THE COCOANUT TREES REPRESENT CORAL ISLETS FORMED ON THE REEF. *CC.* THE LAGOON CHANNEL. *B'B'.* THE SHORES OF THE ISLAND, GENERALLY FORMED OF LOW ALLUVIAL LAND AND OF CORAL DETRITUS FROM THE LAGOON CHANNEL. *A''A''.* THE OUTER EDGES OF THE REEF, NOW FORMING AN ATOLL. *C'.* THE LAGOON OF THE NEWLY FORMED ATOLL. ACCORDING TO THE SCALE, THE DEPTH OF THE LAGOON AND OF THE LAGOON CHANNEL IS EXAGGERATED.

That it is not necessary to call in subsidence to explain any of the characteristic features of barrier reefs or atolls and that all these features would exist alike in areas of slow elevation, of rest, or of slow subsidence.

Alexander Agassiz and Stanley Gardiner were in essential accord with the opinions of Semper and Murray.

[1] Murray, John. On the structure and origin of coral reefs and islands: Roy. Soc. Edinburgh Proc., vol. 10, 1879–1880, pp. 505–518, 1880.

3. The third theory can not be referred to any one man, as it has gradually grown out of the work of many men. Briefly stated it is that offshore reefs have formed on antecedent flattish basements or platforms, during or after submergence, in areas where the ecologic conditions are favorable for the life of reef-building corals. Some of the work of Alexander Agassiz, H. B. Guppy, and R. T. Hill prepared the way for this interpretation, but apparently it was first definitely made by E. C. Andrews[1] as a result of his study of the Great Barrier Reef of Australia, and subsequently Hedley and Griffith Taylor corroborated his conclusions. Later my own studies in Florida, the West Indies, and Central America led me to make for those areas essentially the same interpretation as that of Andrews and Hedley and Griffith Taylor for the Australian Great Barrier.

FIG. 5. Reproduction of J. B. Jukes's section across the Great Barrier Reef of Australia. a. Sea outside the barrier, generally unfathomable. b. The actual barrier. c. Clear channel inside the barrier, generally about 15 or 20 fathoms deep. d. The inner reef. e. Shoal channel between the inner reef and the shore. f. The great buttress of calcareous rock, formed of coral and the detritus of corals and shells. g. The mainland, formed of granites and other similar rocks.

3a. The validity of the theory next to be considered, the Glacial Control theory, is dependent on the soundness of the conclusions expressed in the preceding paragraph. This theory, as is the case with most theories, grew gradually, and ultimately found one chief exponent, who is R. A. Daly.[2] Of course taking water from the ocean to form the continental glaciers of Pleistocene time would lower the level of the surface of the sea during that time to an amount equal to the quantity of water abstracted from the ocean, if there were no crustal movements, such as down-bending due to the weight of the ice caps in high latitudes, that would counteract the effects produced by removal of water from the ocean to form the great ice caps. During Pleistocene time, because of the cold climate of that time, the rate of formation of coral reefs was probably reduced, and, as the protection they afforded shores was thereby lessened, the waves of the sea would then cut extensive submarine plains. With the return of warmer

[1] Preliminary note on the geology of the Queensland coast with reference to the geography of the Queensland and N. S. Wales plateau: Linn. Soc. New South Wales, pt. 2, pp. 146–185, 1902.

[2] The Glacial-Control theory of coral reefs: Amer. Acad. Arts and Sci. Proc., vol. 51, pp. 157–248, 1915.

climatic conditions the great ice caps melted, and the water, thus released, flowed back to the sea, raising its level by an amount equal to the quantity of water returned to it. The warmer waters were favorable for the growth of reef corals, and coral reefs grew luxuriantly on flats, partly formed by Pleistocene wave-cutting, during the period of moderate and gradual submergence following deglaciation.

CRITICAL EXAMINATION OF THE DIFFERENT THEORIES OF THE FORMATION OF CORAL REEFS.

The Semper-Murray theory will be discussed first, for it can be eliminated from further consideration. By referring back to page 217 of this article, it will be seen that present evidence is convincing that neither a lagoon channel nor the lagoon of an atoll can be formed by the solvent effect of sea water in coral reef areas, and as lagoons in general are areas where the deposition of sediment predominates over its removal, they must be explained by an inclosing and not by an excavating process. However, in small areas local destruction may predominate over construction, but such localized destruction will not explain the phenomena presented by lagoons.

Both of the other two explanations are in agreement as regards the part played by submergence in the formation of offshore coral reefs, which include those of the barrier kind, but differ in that according to the Darwin-Dana hypothesis the flat lying shoreward of a barrier is due to infilling and leveling behind the reef, while according to the other explanation the reef has grown upon the surface, usually the outer edge, of a flattish area that antedates the presence of the reef.

The evidence bearing on submergence will be briefly reviewed, beginning with some of the criteria used in inferring such a change in position of land with reference to sea level. One of the first recognized kinds of evidence indicating submergence of the land is the presence of arms of the sea extending into the land area and occupying the lower parts of valleys to be accounted for only by stream erosion operating at altitudes above present sea level. Plate 35, figures D, C, illustrates submerged lower courses of valleys in the islands of Antigua and St. Thomas, West Indies; text figure 9 illustrates a part of the shore of Antigua, where it is deeply indented by arms of the sea that as a result of submergence of the land extend up valleys eroded when the land stood higher above the sea level than it does at the present time. Figure B, of plate 35, illustrates a view looking toward the head of Santiago Harbor, Cuba, and figure A of the same plate is a view looking seaward through the harbor mouth. Text figure 10 illustrates a cross section of Habana Harbor, showing that within the harbor there is a filled channel, which must

have been cut when the land was at least 100 feet higher with reference to sea level than at present. The Cuban harbors are pouch-shaped drainage basins into which the sea has been admitted by submergence of the land. Plate 30 illustrates the basin of Yumuri River and the gorge through which it flows into the sea near Matanzas, Cuba. A slight lowering of the land would convert this basin into a pouch-shaped harbor. There are living coral reefs off the shores of Antigua, St. Thomas, and Cuba, and they have evidently grown upward since the submergence of the former shore lines of those islands. Shore-line phenomena such as these occur around many of the West Indian Islands, along the coasts of Nica-

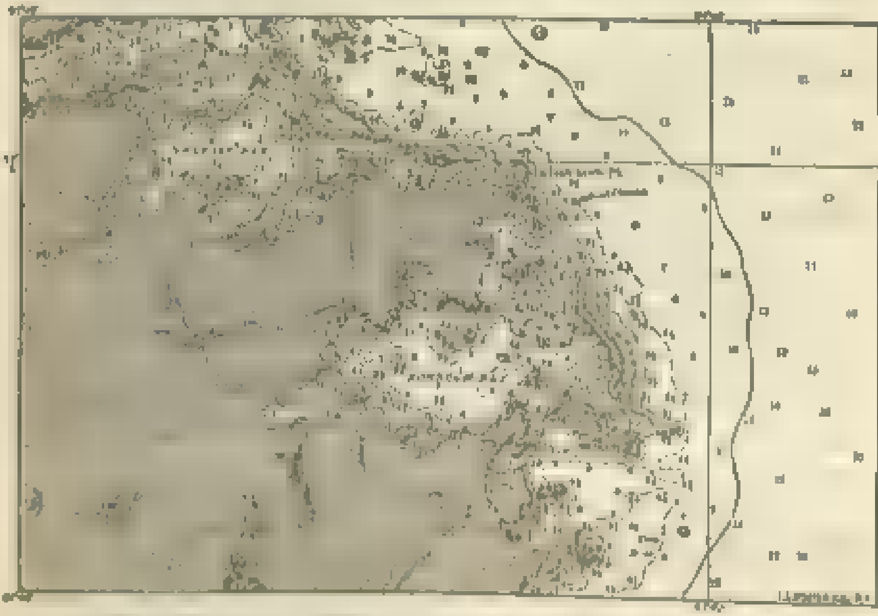


FIG. 9.—CHART OF PART OF EAST COAST OF ANTIGUA. FROM U. S. HYDROGRAPHIC CHART No. [illegible].

ragua and Honduras in Central America and along that of Brazil. Instances of similar phenomena may be seen in New Caledonia, the Society, Fiji, and other islands of the Pacific, and along the Queensland coast, landward of the Great Barrier Reef of Australia.

Where the surface of the land is underlain by limestone, rain water that falls on the earth, instead of eroding stream ways and valleys, in making its way back to the ocean may produce caves and solution-wells by dissolving the limestone because of the carbonic-acid gas it contains. In many areas, such as the Bermudas, the Bahamas, and in places in southern Florida, caverns and solution-wells are found below sea level. Text figure 11 (p. 228), a cross section from the shore of

Andros Island, Bahamas, across the barrier reef, shows the relation of some solution-wells there to the outer reef. The flat between the

FIG. 10.—PLAN AND CROSS SECTIONS OF FILLED CHANNEL IN HAVANA HARBOR. AFTER HARTS, VAUGHAN, AND SPENCER.

reef and the shore has certainly been submerged since the formation of the wells.

Another kind of evidence is the presence undersea of steeply sloping areas of bottom between flat plain surfaces, thereby indicating the submergence of an escarpment or steep slope formed by marginal cutting of the sea, at a time while the land stood high enough for the shore to have been at the escarpment front. (See p. 236 of this article for additional consideration of this criterion.)

The presence below sea level of deposits of peat composed of the remains of land plants is still another kind of evidence. Submerged peat deposits of this kind occur in St. John Harbor, Antigua, and near Key West, Florida.

There are other kinds of evidence, but the four mentioned are sufficient for present purposes. Nearly all of the important living offshore reefs of the world have now been investigated with reference to evidence of submergence, and it has been found that practically all, if not actually all, have formed after an episode of submergence.

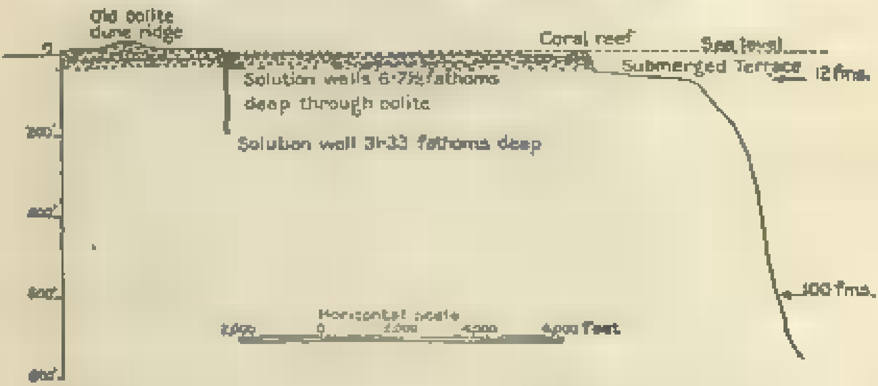


Fig. 11.—Diagrammatic section across the barrier reef, Andros Island, Bahamas.

In the study of fossil reefs the principal criterion for inferring whether they were formed during the submergence of their basements is the nature of the contact between the fossil reef and the immediately underlying geologic formation. If the underlying formation has an uneven upper surface and if pebbles derived from it are incorporated in the overlying reef, the deduction is considered warranted that the basement stood above sea level long enough for it to have been eroded by atmospheric agencies and that it was then brought below sea level before the reef occurring above it began to form. Contacts of the kind indicated are called unconformities. For a number of years I have been studying not only the corals in the fossil reefs of the West Indies and the southern United States, as may be seen by referring back to pages 221, 222 of this paper, but also the geologic relations of the reefs, including the nature of their basal contacts, and the results are given in the following tables:

Stratigraphic relations of West Indian and Canal Zone Eocene and Oligocene reef corals and coral reefs.

Geologic age.	Locality.	Basal contact.
Upper Oligocene.	Canal Zone (Emperador limestone).	Unconformable on Culebra formation.
	Anguilla.	Unconformable on igneous rock or on sandstone and conglomerate.
Middle Oligocene.	Antigua.	Do.
	Porto Rico (Pepino formation).	Do.
	Cuba (Guantanamo).	Do.
Upper Eocene.	St. Bartholomew.	Do.

Stratigraphic distribution of coral reefs and reef corals in the southeastern United States from Oligocene to Recent time, and their relation to changing sea level.

Geologic series.	Geologic formations, members, and unconformities.		Distribution of reef corals and coral reefs.	Change in relation of basement to sea level.
Recent.			Coral reefs.	Submergence.
	Erosion unconformity.			
Pleistocene.	Key Largo limestone.		Do.	Subsidence.
	Erosion unconformity.			
Pliocene.	Caloosahatchee marl.		Reef corals.	Do.
	Erosion unconformity.			
Miocene.	Choctawhatchee marl.		No reefs, a few corals.	Do.
	Erosion unconformity.			
	Alum Bluff formation.	Shoal River marl.	A few corals; slight development of reefs in central and northern peninsular Florida.	Do.
		Oak Grove sand.		
		Chipola marl.	A few corals; 1 species of reef former.	
Oligocene.	Chattahoochee formation.	Upper.	Coral reefs, Tampa, Florida, etc.	Do.
		Lower.	Coral reefs, Bainbridge, Georgia.	Do.
	Erosion unconformity.			
Eocene.	Ocala limestone.		No coral reefs.	Do.

It appears unnecessary to present more evidence on this subject. The result of the examination of the fossil reefs is the same as that obtained from the study of the living reefs—which is that the important offshore reefs have formed during or after submergence. The contacts at the bases of fringing reefs are usually those of unconformity, indicating that the land stood higher and was lowered before the formation of reefs of this kind, but at least many of the fringing reefs were formed during periods of intermittent emergence following submergence.

Have the flats above which offshore reefs rise, either as patches or as barriers, been formed by infilling and leveling behind the reefs, that is, are they dependent on the presence of the reefs, according to the

postulates of the Darwin-Dana hypothesis; or are the flats in origin independent of the existence of the reefs and are the reefs merely superposed on flattish areas that antedate their presence?

There are at least three criteria that are applicable in deciding between these two interpretations. The first of these is the relation of the width and depth of the flat, or platform, to the presence or absence of barrier reefs. If the flat is dependent on the presence of the reef, where a break in the reef occurs there should be a landward projecting reentrant in which the seabottom is deeper than behind the reef. The second criterion consists in the position of the barrier on the surface of the flat. If the flat is due to infilling behind the reef, the reef should stand on its outer edge, not back from the edge with the flat projecting seaward beyond the reef. The third criterion concerns the composition and geologic history of the flat landward of the reef. In many places it is possible to ascertain the nature of the rock forming the sea floor between a barrier and the shore. Such a floor, if formed by agencies associated with the presence of the reef, will not exhibit geologic phenomena that in age antedate the reef; but, on the other hand, if the floor can be shown to be composed of rock older than the reef, or to have had any kind of geologic history antecedent to the presence of the reef, it is demonstrated that the reef is merely growing on the surface of a flat whose formation is independent of the reef development.

The Great Barrier Reef of Australia is definite in its testimony. Text figure 12 presents cross sections south of the reef limits and across the reef tract. Profiles 1, 2, and 3, which are south of the southern end of the reef, show the continuity of the platform southward beyond the end of the reef; while profiles 4 and 5 show the platform projecting some miles beyond the reef. At its northern end the reef appears usually to stand on the seaward edge of the platform or shelf. The continuity of barrier platforms irrespective of the presence or absence of reefs is general off the shores of large land areas. Plate 38 is from a photograph of a model of the Gulf of Mexico and the Carribbean Sea. There are offshore reefs on the Floridian Plateau, and on both Campeche and Mosquito banks, but a person would indeed be bold to contend that these features of the earth's crust are due to infilling behind reefs, especially when some additional facts presented in the next paragraphs are considered.

The geologic succession of the reef-coral faunas of Georgia and Florida is given in the table on page 229. The geographic extent and composition of the Ocala limestone, of late Eocene age, which forms the basement of the Floridian Plateau, have been ascertained

with considerable exactness. Its surface outcrop has been mapped in Georgia and Florida, and well borings have revealed its presence under younger formations in west Florida at Panama City, and in peninsular Florida at Tampa, Key West, Key Vaca, and Palm Beach. The limestone is largely composed of the remains of myriads of *Nummulites* and orbitoidal Foraminifera, many Bryozoa, and some mollusks and echinoids, with which there seems to be an undetermined proportion of chemically precipitated calcium carbonate and some terrigenous material. Corals are everywhere rare and as a rule are absent. The organisms occurring in the formation are

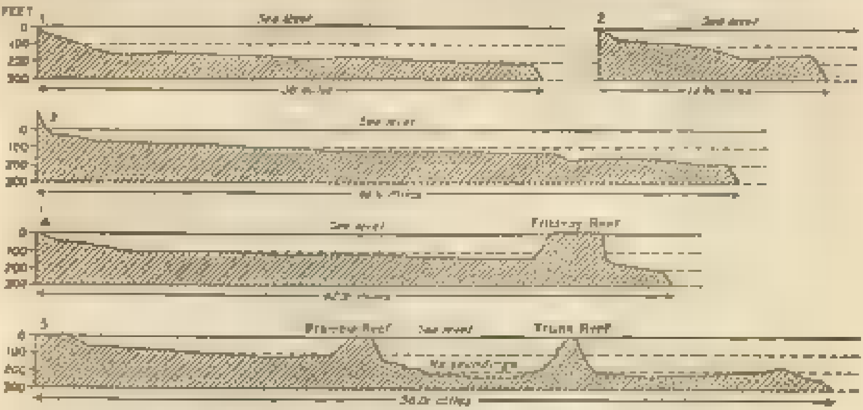


FIG. 12.—PROFILES ACROSS CONTINENTAL SHELF, EAST SIDE OF AUSTRALIA. THE LATITUDE AT THE INTERSECTION OF EACH PROFILE WITH THE SHORE LINE IS FOLLOWED BY THE STATEMENT OF THE DIRECTION OF THE PROFILE FROM THE SHORE.

SOUTH OF THE SOUTHERN END OF THE GREAT BARRIER REEF.

1. FROM SHORE EAST OF LEADING HILL, S. LAT. 25° 28' 15", SOUTH 82° EAST.
2. FROM BASE OF SANDY CAPE, S. LAT. 24° 53' 40", NORTH 68° EAST.
3. FROM TOOWONG HILL, S. LAT. 24° 22' 4", NORTH 45° EAST, PASSING BETWEEN LADY ELLIOT AND LADY MUSGRAVE ISLANDS.

ACROSS THE GREAT BARRIER REEF.

4. FROM RODD PENINSULA, S. LAT. 24° 0' 0", NORTH 50° EAST.
5. FROM GEORGE POINT, HINCHINBROOK ISLAND, S. LAT. 18° 25' 40", NORTH 72° 32' EAST.

characteristic of tropical shoal water, 50 fathoms or less in depth; and, as the 100-fathom curve delimits the submerged border of the Coastal Plain, it is evident that the Floridian Plateau has been a part of the Coastal Plain and has had essentially its present outline since late Eocene time, *before the formation of the oldest Chattahoochee reef*, which was therefore superposed on a subsiding platform not produced by corals. The geologic history of the Floridian Plateau shows that each successive development of Tertiary reefs was on an antecedent platform which was formed by agencies not dependent on the presence of coral reefs, and in all instances the volume of coral as compared with material from other sources is

of minor and usually of negligible importance. The accompanying map shows the location of the Oligocene and Miocene reefs and reef corals of Florida and Georgia with reference to the plateau surface.

The evidence of these fossil reefs is the same as that of the living Australian, Floridian, and Central American reefs. But this is not all. There are off the eastern shores of North America three banks at such a depth that coral reefs might grow on them were they within the proper climatic zone. These banks are Georges

FIG. 12.—FLORIDA, OCALA LIMESTONE PLATEAU WITH SUPERPOSED OLIGOCENE AND MIOCENE CORAL REEFS AND REEF CORALS. OC. LS.—OCALA LIMESTONE; THE FIGURES ARE FOR THE DEPTHS OF ITS UPPER SURFACE BELOW SEA LEVEL. CH.—CHATTAHOOCHEE AND TAMPA OLIGOCENE FORMATIONS. AL. B.—ALUM BLUFF MIOCENE FORMATION.

Bank off Nantucket, the banks off the coast of Nova Scotia, and the Grand Banks of Newfoundland. Such banks are not confined to the coral reef zone.

Text figure 11, page 228, of this article shows solution wells through the oolite between the shore and the barrier reef off the east side of Andros Island, Bahamas. The flat between the reef and the shore must have existed before the present reef formed in order that those holes, now submerged, might be made in it. In the West Indies in

general the living reefs are growing on antecedent platforms that have been submerged in geologically Recent time. There are continuous platforms and discontinuous reefs in New Caledonia, the Fiji Islands, and Tahiti, and such relations, which are certainly usual, if not entirely general, are *not* in accord with the Darwin-Dana hypothesis. Information on the small islands of the Society

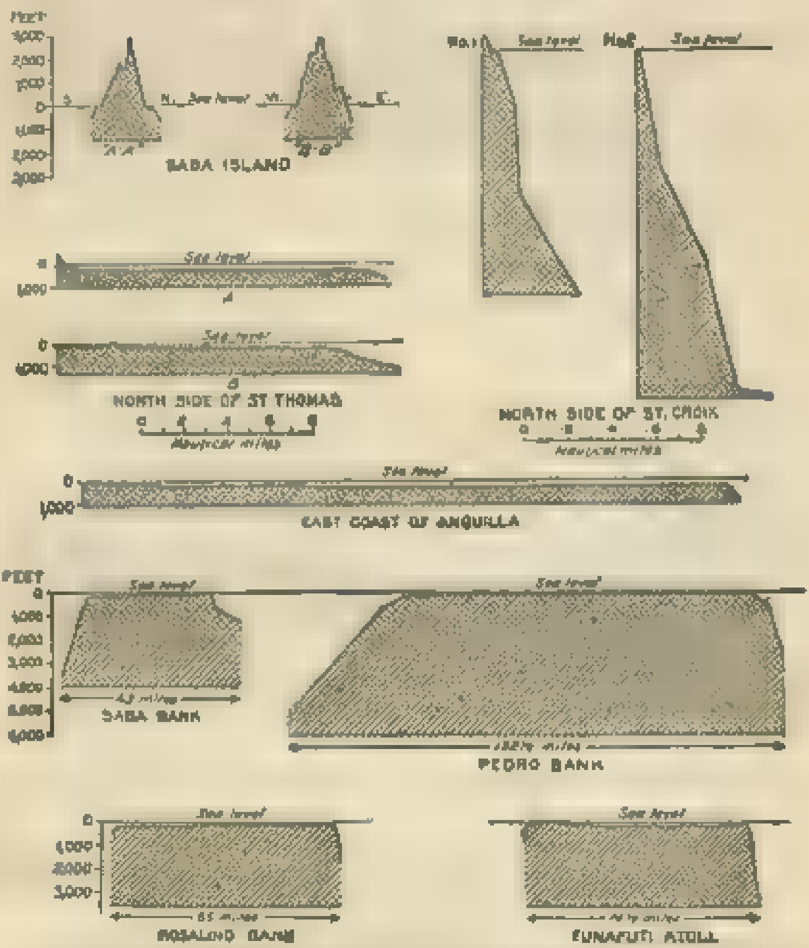


FIG. 14.—TYPES OF WEST INDIAN SUBLITTORAL PROFILES AND PROFILE OF FUNAFUTI ATOLL.

group. Murea, Huaheine, Raiatea, Bora-Bora, etc., is inadequate for a definite statement, and there is controversy as to whether the reefs are growing on previously formed flats or whether the flats are due to infilling behind the reefs.

West Indian Islands sublittoral profiles are interesting in this connection, and are represented by text figure 14. There are no offshore reefs where no platforms have been developed, as off the young vol-

canic island Saba, and the steep shore along the north side of St. Croix. The presence of a flat seems necessary to initiate vigorous coral growth.

Only a few paragraphs will be devoted to atolls, of which there are two kinds. Those of the first kind are ring-shaped segments of long reefs that rise above shallow platforms, such as the atolls of the Great Barrier Reef of Australia and the Tortugas atoll of Florida. These are shaped by currents that are mostly wind-induced. The convex sides of such atolls are toward the wind and the open sides are to the leeward. The accompanying diagram, copied from Hedley and Griffith Taylor, illustrates the principles of their formation. That there never was any central land area in such atolls is obvious. The other kind of atolls is those whose rims more or less completely margin the flat summit areas of submarine mountains or plateaus that almost reach the surface of the sea. This kind of atolls was the subject of special study by Admiral Wharton,[1] of the British Navy, who pointed out the uniformity of the depth of the lagoon floors, and stated, as Chamisso years previously had done, that the margining reefs are only more or less continuous. He also laid special stress on the fact that the flat floors of the lagoons did not accord with Darwin's hypothesis, according to which they should be concave, more or less bowl-shaped, and expressed the opinion that the summits had been leveled by marine erosion previous to the formation of the atoll rims. It appears to me that the most plausible explanation of atolls is that they have formed on flat summit areas during moderate submergence.

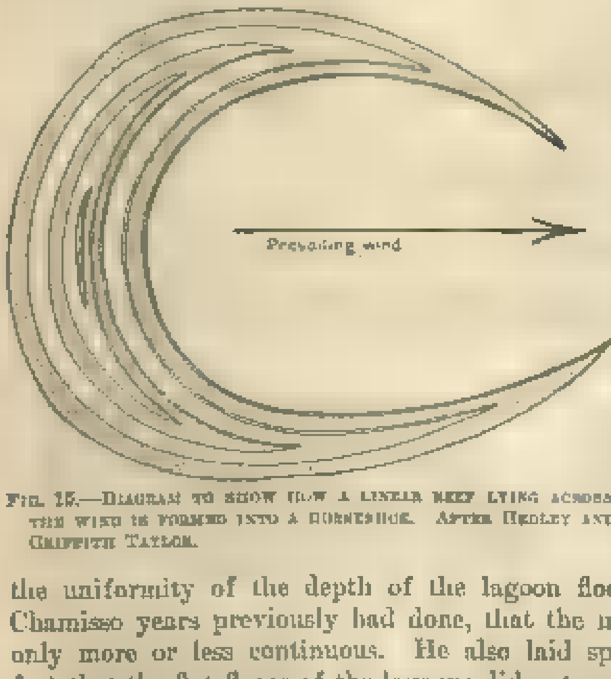


FIG. 15.—DIAGRAM TO SHOW HOW A LINEAR REEF LYING ACROSS THE WIND IS FORMED INTO A HORSESHOE. AFTER HEDLEY AND GRIFFITH TAYLOR.

In reply to a criticism of my interpretation of the relations of offshore reefs to the platforms above which they stand because I have not attempted to explain the origin of the platforms,[2] I may say that

[1] Wharton, W. J. L., Foundations of coral atolls: Nature, vol. 55, pp. 390–393, 1897.

[2] Davis, W. M., The origin of coral reefs: Nat. Acad. Sci. Proc., vol. 1, pp. 146–152, March, 1915.

the recognition of the fact that books, papers, inkstands, etc., are on the top of a desk does not require knowledge of the process of manufacture of the desk or even of the material out of which it is made; and that one geologic formation overlies another may be ascertained without having complete knowledge of the geologic history of either the overlying or the underlying formation.

That the origin of the submarine flats on which offshore reefs stand should be understood is important in the advancement of our knowledge of geologic history, and I have acquired as much information on the subject as I could. I am convinced that there is no one explanation that can be applied to all of them. The following kinds of flats have already been recognized: (1) Slightly tilted bedded tuffs, as in the fossil reefs of Antigua; (2) slightly tilted bedded limestones, as off the south coasts of St. Croix and Cuba; (3) submerged coastal flats, as in the Fiji Islands; (4) submerged peneplained surfaces, as in the fossil reefs of Porto Rico; (5) submarine plains due to uplift of considerable areas of the ocean bottom and to the deposition of organic deposits on such a surface, as the Floridian Plateau prior to the formation of the middle and upper Oligocene reefs of Florida and southern Georgia; (6) flats of complex and not definitely known origin, such as those of the Antigua-Barbuda Bank, the Virgin Bank, and the continental shelves of tropical America and Australia.[1] Plains suitable for the growth of corals have been formed by subaerial and submarine deposition, and by both subaerial base-leveling and submarine planation. Nearly every, if not every, plain-producing process operative in tropical and subtropical regions has taken part in the formation of plains on which coral have grown or are growing where the plains have been brought below sea level and where the other ecologic conditions for offshore reef formation obtain. Although, as regards coral reefs, I wish to emphasize the independence of those platforms concerning which information is available, I wish also to make it clear that I recognize that in-filling does take place behind reefs, but that such in-filing is not sufficient in amount to account for the flats above the surfaces of which the reefs stand.

The Glacial Control theory will now be considered in more detail. If this theory is true the following conditions should now prevail:

---

[1] Professor Davis, in an article entitled "The Great Barrier Reef of Australia," published in the Amer. Jour. Sci., 4th ser., vol. 44, pp. 339–350, November, 1917, proposes the hypothesis that the platform on which the living Great Barrier Reef is growing resulted from in-filling behind a barrier until a "mature reef plain," according to his terminology, was formed. Although this is an interesting hypothesis, it is at present not possible to procure decisive information on the processes whereby the Australian continental shelf was produced.

(a) There should be evidence of geologically Recent submergence of most of the shore lines of the earth; (b) the average amount of the submergence should be equal to the amount of lowering of the ocean level during Pleistocene glaciation: (c) the position of the shore line during Pleistocene glaciation should be indicated by scarps separating flats, and the amount of submergence indicated by their present position below sea level should agree with the amount of the raising of ocean level due to deglaciation; (d) the rate of growth corals should be such that since the disappearance of the continental ice sheets coral reefs could grow to a thickness equal to the amount sea level was raised as a result of deglaciation; (e) living barrier coral reefs and atoll reefs should be superposed on antecedent basement flats or platforms. It should here be stated that the fact that there has been local differential crustal movements does not at all invalidate the importance of the Glacial Control theory in its application to the explanation of modern coral reef development.

In the foregoing discussion it has been shown that within coral-reef regions there has been geologically Recent submergence. The shore lines of the earth can not be reviewed in this place, but it may be said that the available evidence indicates that the sea has recently, geologically speaking, overflowed the seaward margins of the land. According to estimates by W. J. Humphreys[1] and by Daly the maximum amount of the lowering of sea level because of the abstraction of water from the ocean to form the continental ice sheets was of the order of magnitude of 67 meters (about 36 fathoms). Daly has made elaborate compilations of the depths of lagoons, lagoon channels, and drowned valleys, in the coral reef areas of the Pacific and Indian Oceans; and the lowering of sea level, between 55 and slightly more than 37 meters, indicated by the compilations agrees with the computations about as closely as should be expected. I obtained similar results in the West Indies. The accompanying text figure 16 indicated a raising of sea level in excess of 37 meters (20 fathoms), on the basis of interpreting the steeper slope at a depth below 20 fathoms as a marginal sea-cut scarp that has been submerged. A similar steeply sloping facet is shown in the profile of the Australian platform, text figure 12. The statement on the growth-rate of corals shows that any known living coral reef could have grown to its estimated thickness since the disappearance of the continental ice sheets, calculated to have been between 10,000 and 30,000 years ago; and finally, so far as definite information has been procured, living offshore coral reefs are superposed on basement platforms that have been recently submerged. I am entirely convinced that glacial control is one of the most important factors in bringing about the

[1] Changes of sea level due to changes of ocean volume: Washington Acad. Sci. Jour., vol. 5, pp. 445–446, 1915.

great development of coral reefs at the present time. However, I am not in agreement with Daly in attributing so much work to marine abrasion while the level of the sea was lowered during Pleistocene time. It seems to me that most of the platforms are of pre-Pleistocene age, and were wave-cut and remodeled around their edges during Pleistocene time; but this is a subject that needs much more investigation.

It should be stated that the raising of ocean level because of deglaciation will not explain the formation of all coral reefs, for in places, as in some of the Fiji Islands, according to W. G. Foye,[1] the submergence of the reef basements is due to the tilting of previously flat-lying areas, on the submerged part of which reefs have formed after the tilting. In other areas there is clear evidence of tilting and warping as in the Bahamas and Florida. General submergence because of deglaciation is concomitant with local crustal deformation. How the submergence produced is, as regards corals, unimportant, provided there be gradual submergence of moderate amount.

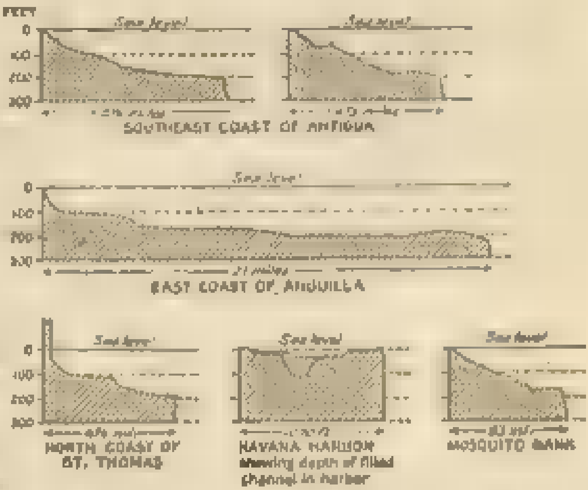


FIG. 16.—SUBMARINE PROFILES OFF WEST INDIAN ISLANDS AND ACROSS MOSQUITO BANK.

CONCLUSIONS.

The following are my conclusions on the formation of coral reefs:

(1) Fringing reefs seem uniformly to have unconformable basal contacts; they may form after submergence that is not followed by uplift or they may form during intermittent uplift that follows submergence—that is, they may form during either emergence or submergence.

(2) Offshore coral reefs, barriers and atolls, form on antecedent flattish basements during and after submergence in areas where the general ecologic conditions suitable for reef-coral growth prevail, as stated on page 215. This generalization applies to fossil as well as to living reefs.

[1] The geology of the Fiji Islands: Acad. Nat. Sci. Proc., vol. 3, pp. 305–310, April, 1917.

(3) Recent rise of sea level because of deglaciation has made conditions favorable for coral reef formation over enormous areas, and it is one of the important factors in causing the great development of coral reefs at the present time. But in some areas, as in the Fijis, the flats on which the reefs are growing are coastal flats that have been brought below sea level by tilting, as described by Andrews and Foye.

(4) The theoretic possibility of the progressive change of a fringing reef into a barrier and later into an atoll, according to the Darwin-Dana hypothesis, may not be denied, but no instance of such a transformation has as yet been discovered.

(5) The results of the investigation of coral reefs are valuable to geology not so much because of discoveries immediately concerning corals as because of the additions to knowledge obtained through a study of great complexes of geologic phenomena among which corals and coral reefs are only incidents. Further investigations of the phenomena associated with coral reefs are among the pressing desiderata of geologic research.

EXPLANATIONS OF PLATES.

Plate 1.

Illustrations from photographs, natural size, of two Blaschka models of sea-anemones.

Fig. 1. *Cerianthus lloydi* Gosse.

2. *Heliactis bellis* (Ellis and Solander).

1

2

BLASCHKA GLASS MODELS OF SEA ANEMONES.

1. LEPTASTREA PURPUREA (DANA). 2. GONIASTREA PECTINATA (EHRENBERG).
3, 3A. MILLEPORA TRUNCATA (DANA).

PLATE 2.

FIG. 1. *Leptastrea purpurea* (Dana). Calices, × 4, to show the formation of new calices by budding between the older ones.

2. *Goniastrea pectinata* (Ehrenberg). Calices, × 4, to show the formation of new calices by the division of the older ones.

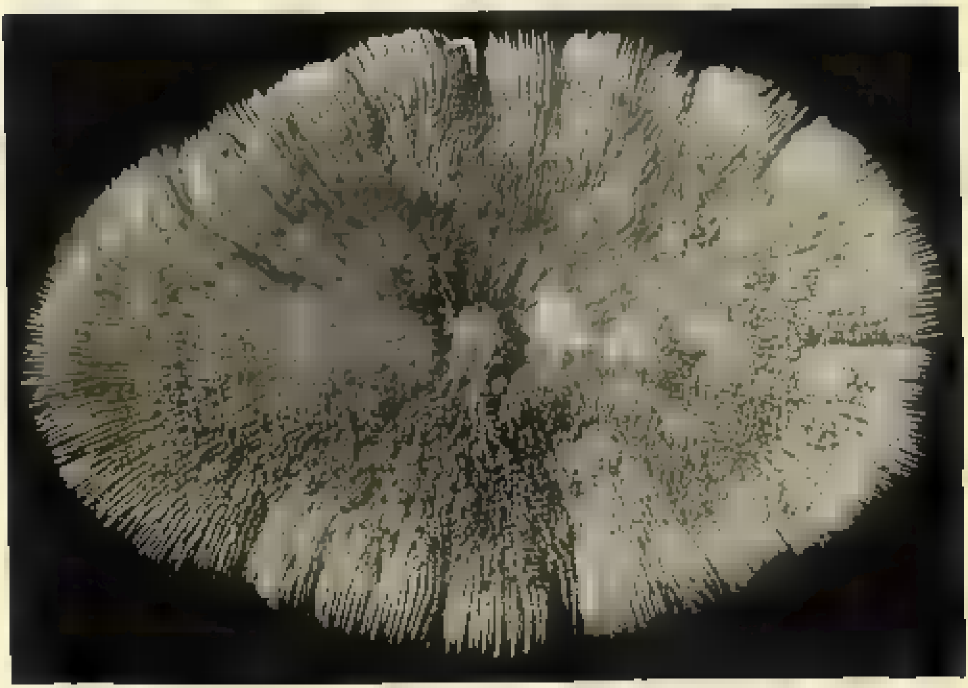
3, 3a. *Millepora truncata* Dana. Fig. 3, the skeleton, natural size; fig. 3a, part of the surface, × 5, to show the larger gastropores and smaller dactylopores.

PLATE 3.

Fungia scutaria Lamarck.

FIG. 1. Upper surface; fig. 1a, lower surface, both natural size.

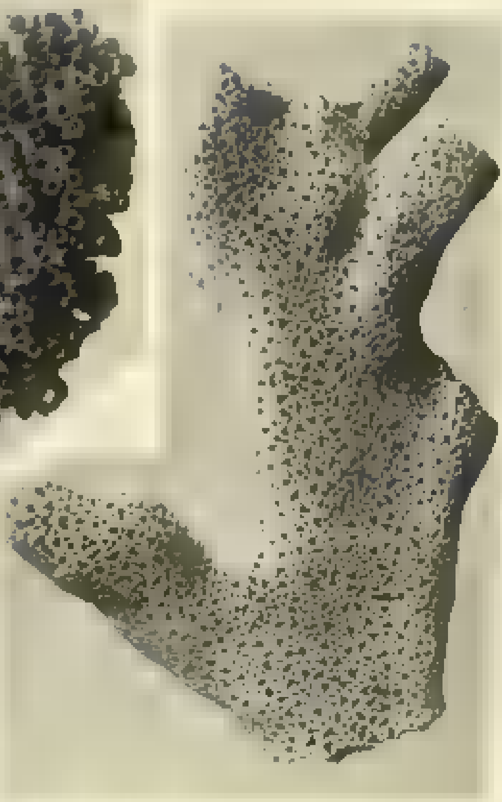
1



1a

FUNGIA SCUTARIA LAMARCK.

1



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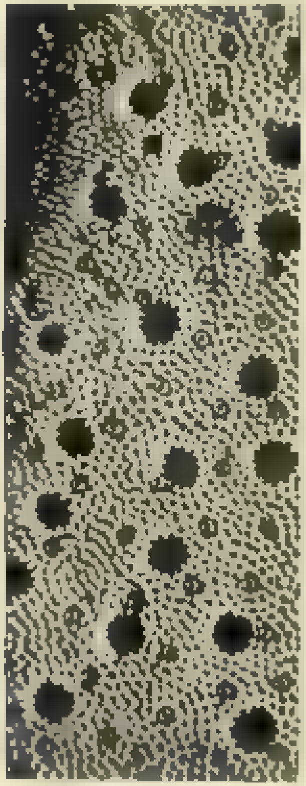
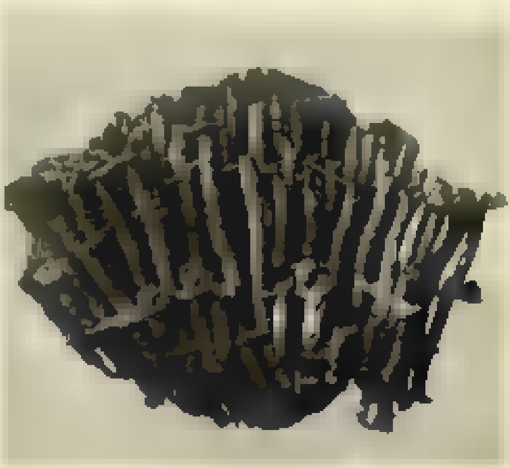


2a × 6



1a

1, 1a. ORGAN-PIPE CORAL, TUBIPORA SP. 2, 2a. BLUE CORAL, HELIOPORA CAERULEA (PALLAS).

PLATE 4.

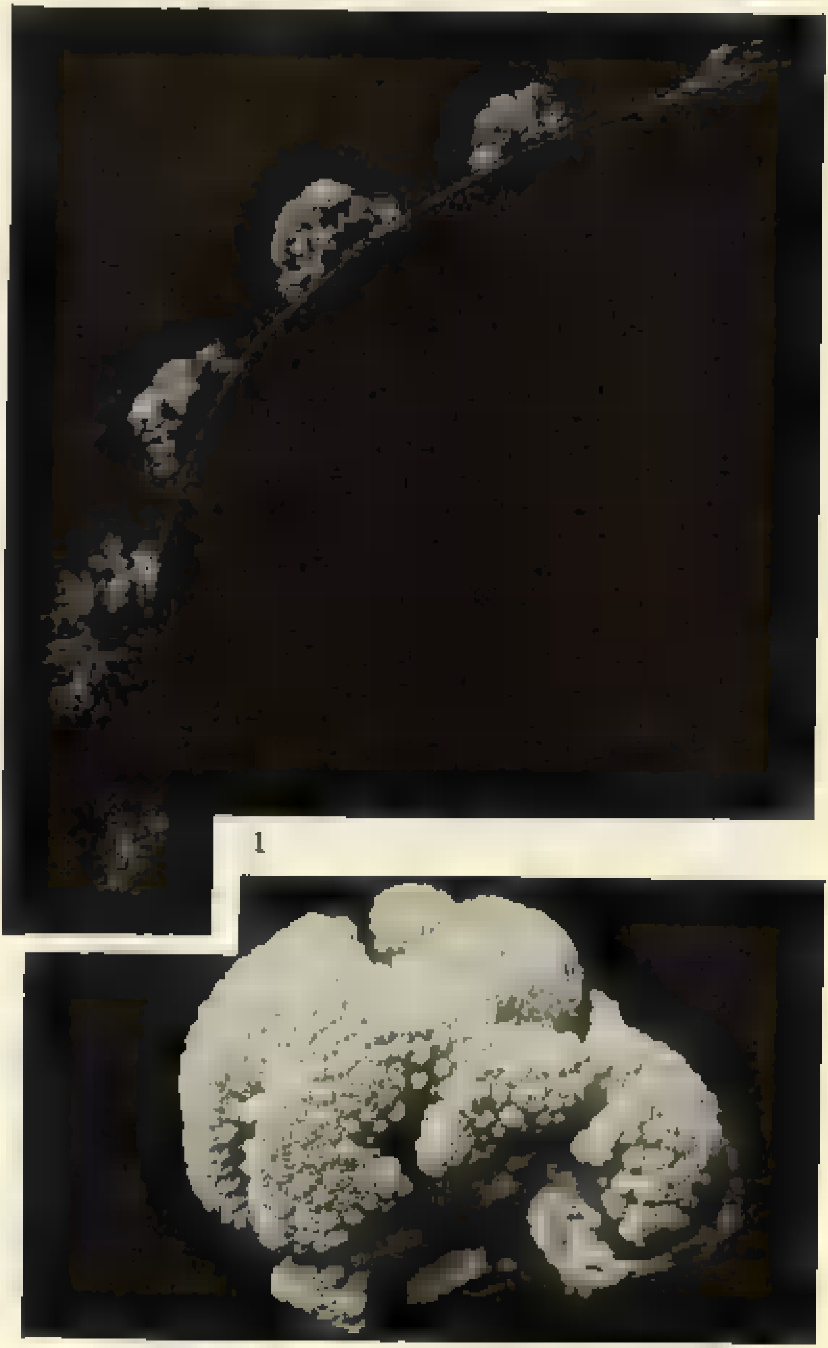
FIGS. 1, 1*a*. Organ-pipe coral, *Tubipora* sp. Fig. 1, upper surface; fig. 1*a*, side view, both natural size.

2, 2*a*. Blue coral, *Heliopora coerulea* (Pallas). Fig. 2, corallum, natural size; fig. 2*a*, surface, × 6.

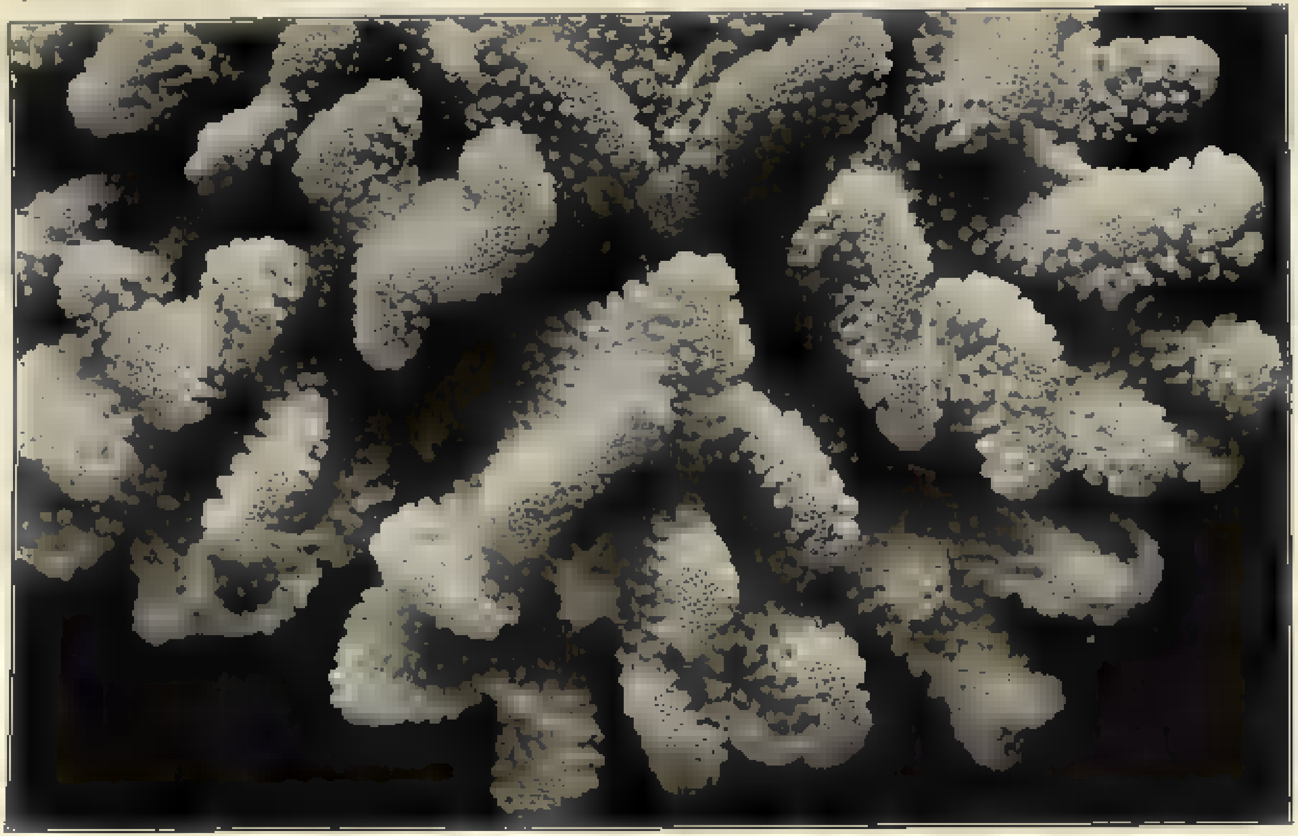
PLATE 5.

FIG. 1. Specimen of *Pocillopora bulbosa* Ehrenberg, as attached to a log in Cocos-Keeling Islands. From a photograph kindly supplied by Dr. F. Wood Jones.

2. *Pocillopora elegans* Dana, natural size. A specimen from the outer barrier, Cocos-Keeling Islands. The rough water facies of the species.



1. POCILLOPORA BULBOSA (EHRENBERG). 2. POCILLOPORA ELEGANS (DANA.)



POCILLOPORA ELEGANS (DANA).

PLATE 6.

Pocillopora elegans Dana.

A part, natural size, of Dana's type from the Fiji Islands. This is the same as the quieter-water facies of the species found in Cocos-Keeling Islands.

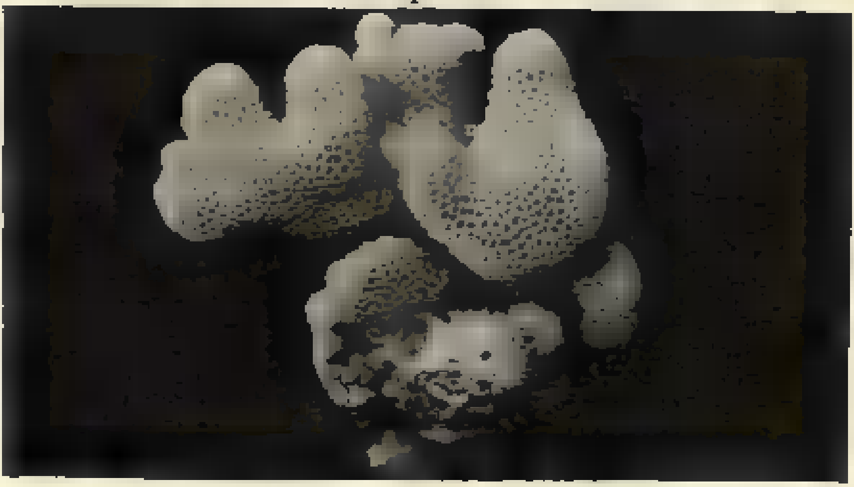
65183°—SM 1917——17

PLATE 7.

Stylophora pistillata (Esper), from Murray Island, Australia.

FIG. 1. From quiet, rather deep water, depth 18 fathoms.
2. From the exposed seaweed edge of the reef.
Both figures natural size.

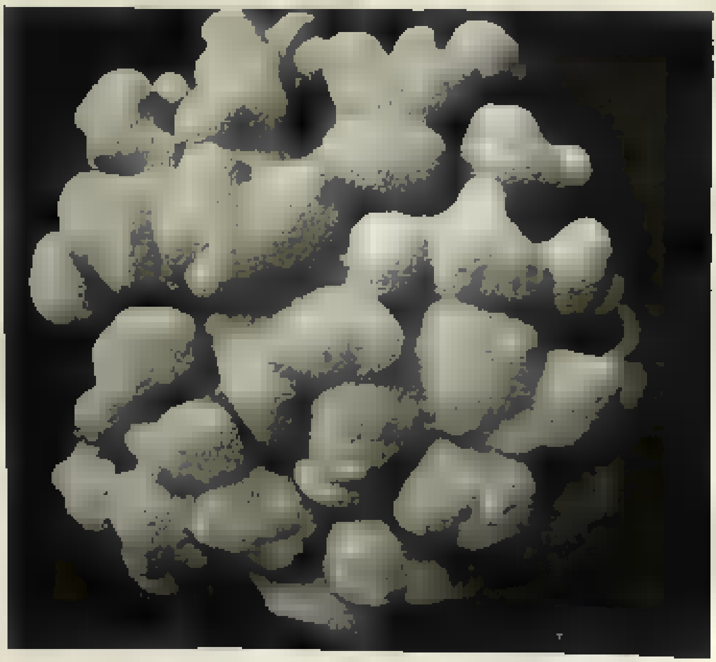
1



2

STYLOPHORA PISTILLATA (ESPER).

1



2

PORITES PORITES (PALLAS).

PLATE 8.

Porites porites (Pallas), from Tortugas, Florida.

FIG. 1. Quiet water, lagoon facies.
2. Exposed reef facies.
Figures about one-half natural size.

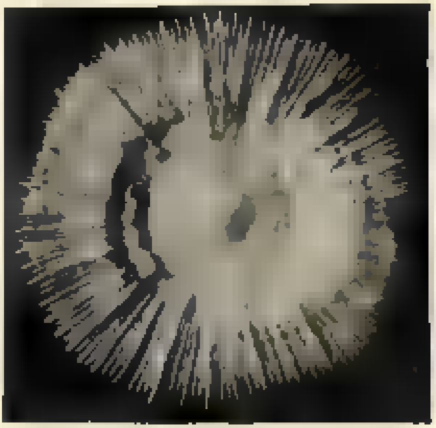
PLATE 9.

Hawaiian corals obtained between 25 and 40 fathoms (46 and 74 meters) in depth.

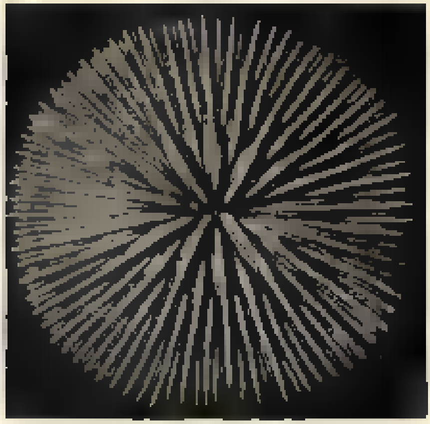
FIGS. 1, 1a. *Fungia patella* (Ellis and Solander), two views, natural size, of the same specimen. Fig. 1, upper surface; fig. 1a, lower surface.

2, 2a. *Fungia* (*Diaseris*) *fragilis* (Alcock), two views, about twice natural size, of the same specimen. Fig. 2, upper surface; fig. 2a, lower surface.

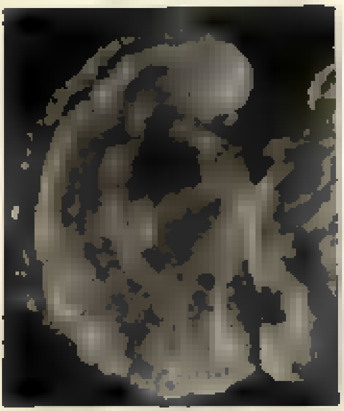
3. *Leptoseris digitata* Vaughan, × 2.



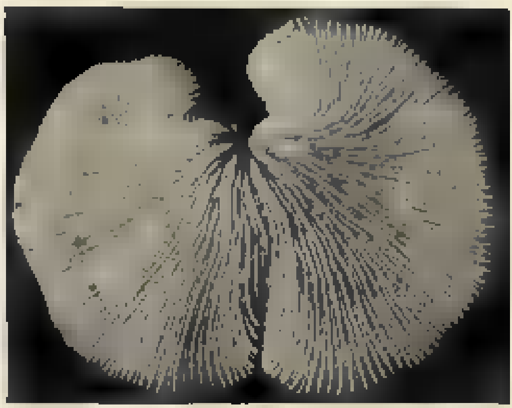
1a



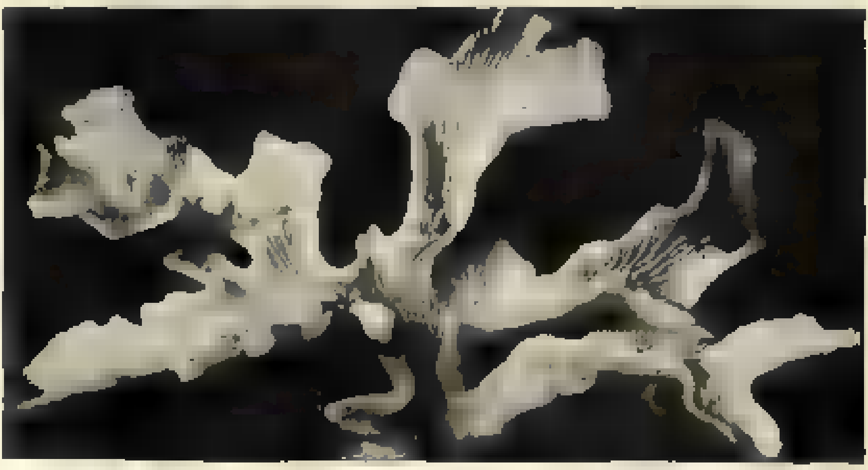
1



2a

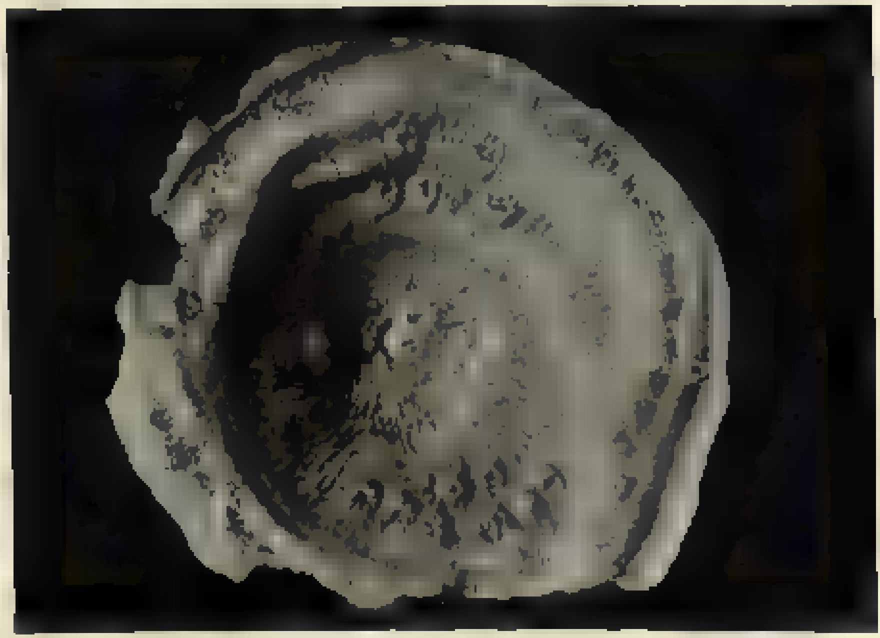


2

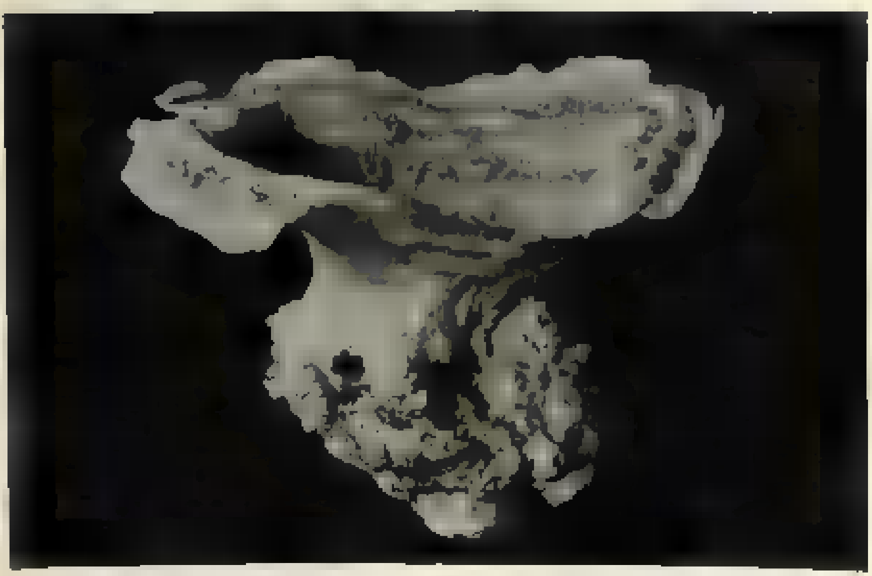


3

HAWAIIAN CORALS OBTAINED BETWEEN 25 AND 40 FATHOMS (46 AND 74 METERS) IN DEPTH.



1



1a

HAWAIIAN CORALS OBTAINED BETWEEN 25 AND 40 FATHOMS (46 AND 74 METERS) IN DEPTH.

Plate 10.

Hawaiian corals obtained between 25 and 40 fathoms (46 and 74 meters) in depth.

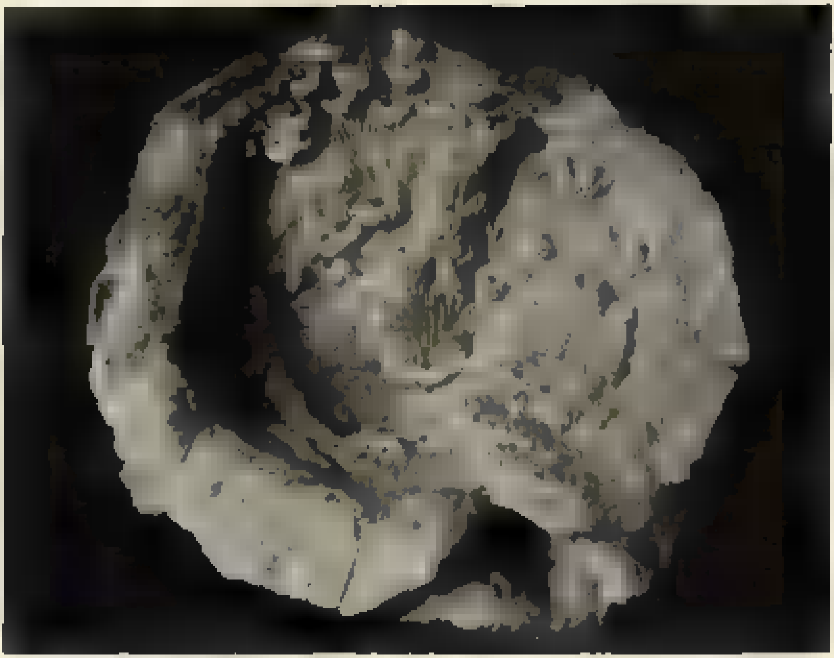
Leptoseris hawaiiensis Vaughan.

Fig. 1. Upper surface; fig. 1a, side view, each natural size.

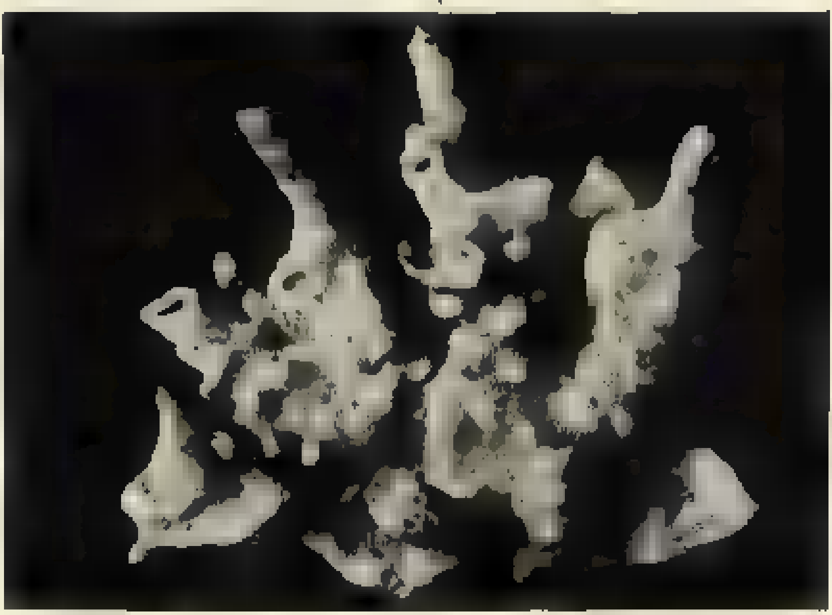
PLATE 11.

Hawaiian corals obtained between 25 and 40 fathoms (46 and 73 meters) in depth.

FIG. 1. *Leptoseris scabra* Vaughan. Upper surface, natural size.
2. *Leptoseris tubulifera* Vaughan. General view, × 2.



1



2 × 2

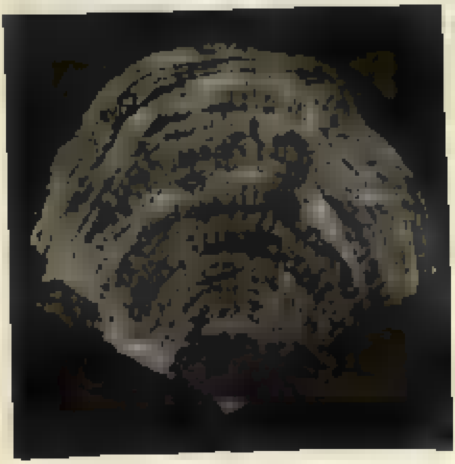
HAWAIIAN CORALS OBTAINED BETWEEN 25 AND 40 FATHOMS (46 AND 74 METERS) IN DEPTH.

1a ×2

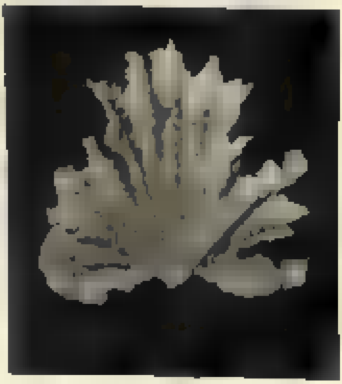
1 ×2

3a

2a



2



3

HAWAIIAN DEEP-SEA CORALS.

PLATE 12.

Hawaiian deep-sea corals.

FIGS. 1, 1a. *Caryophyllia hawaiiensis* Vaughan. Fig. 1, side view; fig. 1a, calice, of the same specimen, each × 2.

2, 2a. *Flabellum paripavoninum* Alcock. Fig. 2, side view; fig. 2a, calice of the same specimen, both natural size.

3, 3a. *Flabellum deludens* von Marenzeller. Fig. 3, side view; fig. 3a, calice of the same specimen, both natural size.

PLATE 15.

Hawaiian deep-sea corals.

FIGS. 1, 1*a*. *Desmophyllum cristagalli* Milne Edwards and Haime. Fig. 1, side view, natural size; fig. 1*a*, calice, × 2, of the same specimen.

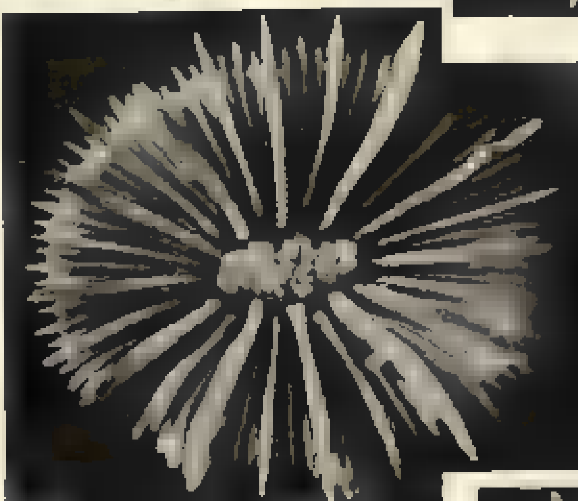
2, 2*a*. *Cyathoceras diomedeae* Vaughan. Fig. 2, side view, natural size; fig. 2*a*, calice, × about 2, of the same specimen.

3, 3*a*. *Caryophyllia alcocki* Vaughan. Fig. 3, side view, natural size; fig. —.

3*a*, calice, × 2 1/2, of the same specimen.

1

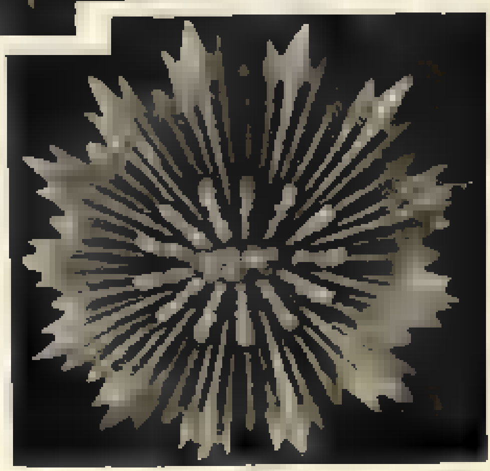
1a × 2



× 2 2a

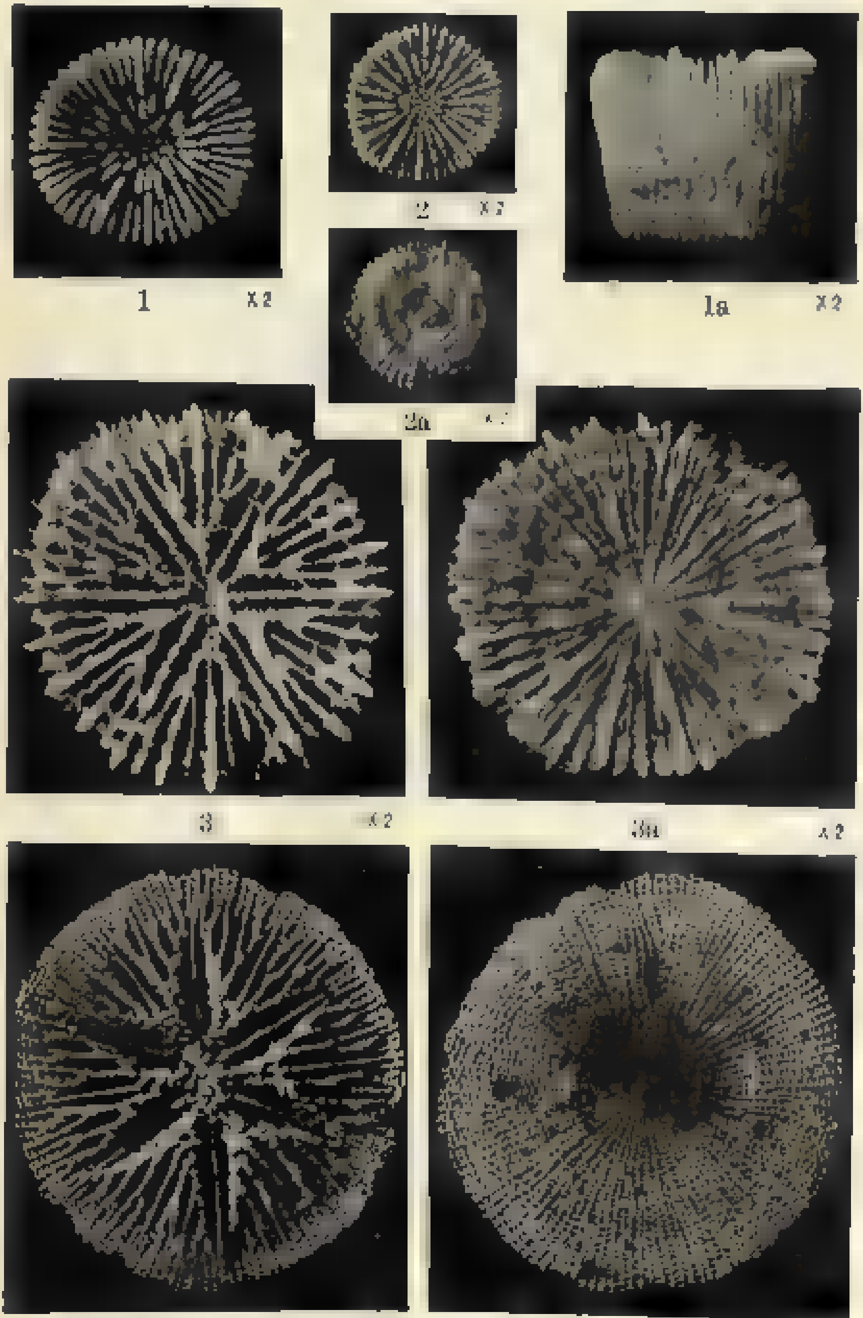
3

2



3a × 2½

HAWAIIAN DEEP-SEA CORALS.



HAWAIIAN DEEP-SEA CORALS.

PLATE 14.

Hawaiian deep-sea corals.

FIGS. 1, 1*a*. *Paracyathus gardineri* Vaughan. Fig. 1, calice; fig. 1*a*, side view, of the same specimen, both × about 2.

2, 2*a*. *Anthemiphyllia pacifica* Vaughan. Fig. 2, calice; fig. 2*a*, base, of the same specimen, both × 2.

3, 3*a*. *Bathyactis hawaiiensis* Vaughan. Fig. 3, calice; fig. 3*a*, base, of the same specimen, both × 2.

4, 4*a*. *Stephanophyllia formosissima* Mosely. Fig. 4, calice; fig. 4*a*, base, of the same specimen, both × 2.

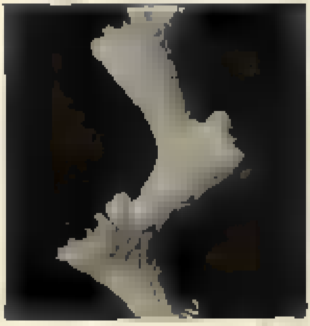
PLATE 15.

Hawaiian deep-sea corals.

FIGS. 1, 1a. *Madrepora kauaiensis* Vaughan. Fig. 1, corallum, natural size; fig. 1a, part of a branch, × 4½, of the same specimen.

2. *Madracis kauaiensis* Vaughan, corallum, natural size.

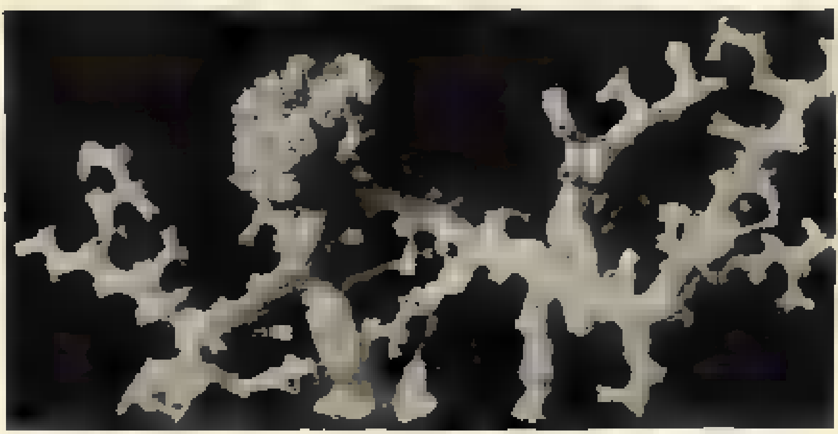
3. *Anisopsammia amphelioides* (Alcock), part of a corallum, natural size.



1a

2

3



1

HAWAIIAN DEEP-SEA CORALS.

A.

B.

C.

VIEWS AT FORT JEFFERSON, TORTUGAS, FLA.

PLATE 16.

Fort Jefferson, Tortugas, Florida.

FIG. A. Wharf. Many corals are growing on the peripheral piers.
B. The moat and sallyport. Corals of lagoon facies live in the moat.
C. Outside of the moat wall and the flood-gate, the northwest side of the fort. Many corals were planted near the wall, north of the flood-gate.

PLATE 17.

Maeandra areolata (Linnaeus).

The tentacles are fully distended, following stimulation by a small amount of food. The figure is about 1.4 natural size.

MAEANDRA AREOLATA (LINNAEUS), WITH ITS TENTACLES FULLY DISTENDED.

MAEANDRA AREOLATA (LINNAEUS), WITH THE POLYPS PARTIALLY CONTRACTED.

PLATE 18.

Maeandra areolata (Linnaeus).

The same colony represented by plate 17, as it appeared during the digestion of food. The figure is about 1.4 natural size.

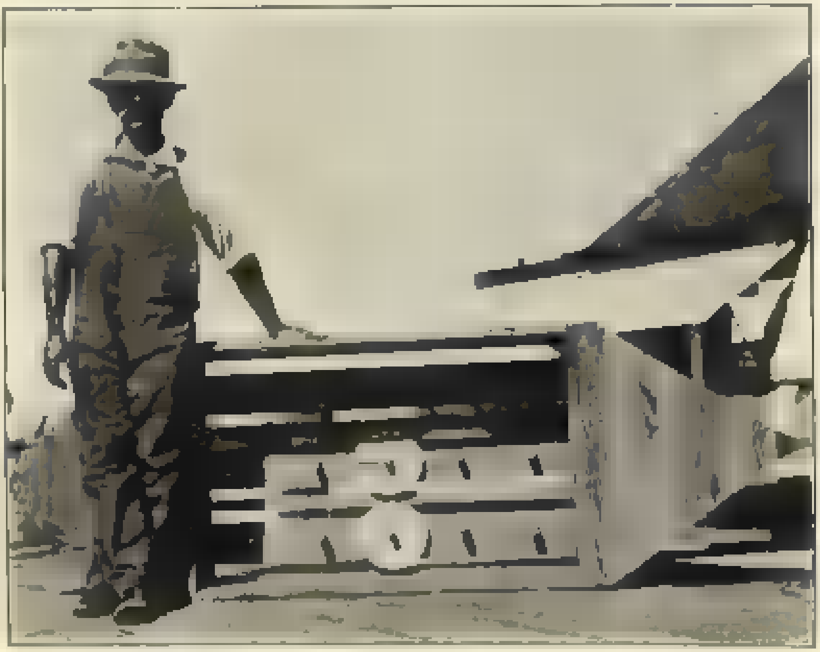
PLATE 19.

FIG. A. Aquarium at the laboratory, Tortugas, Florida. The jars on the lowest shelf contained coral planulae that were being reared; the jars on the next higher shelf contained clean seawater that was siphoned to the jars below; the jars on the top shelf contained coral colonies from which the planulae for the rearing experiments were obtained.

B. Apparatus for planting corals. A, terra-cotta disc (8 inches in diameter), to which corals were attached; B, iron bar, the lower end a cap that fits over the heads of the iron stakes; C, iron stake with a terra-cotta disc in place on its head; D, sledge hammer.

A. AQUARIUM AT THE LABORATORY, TORTUGAS, FLA.

B. APPARATUS FOR PLANTING CORALS.



A.

B.

LIVE CAR IN WHICH CORALS WERE PLANTED.

PLATE 20.

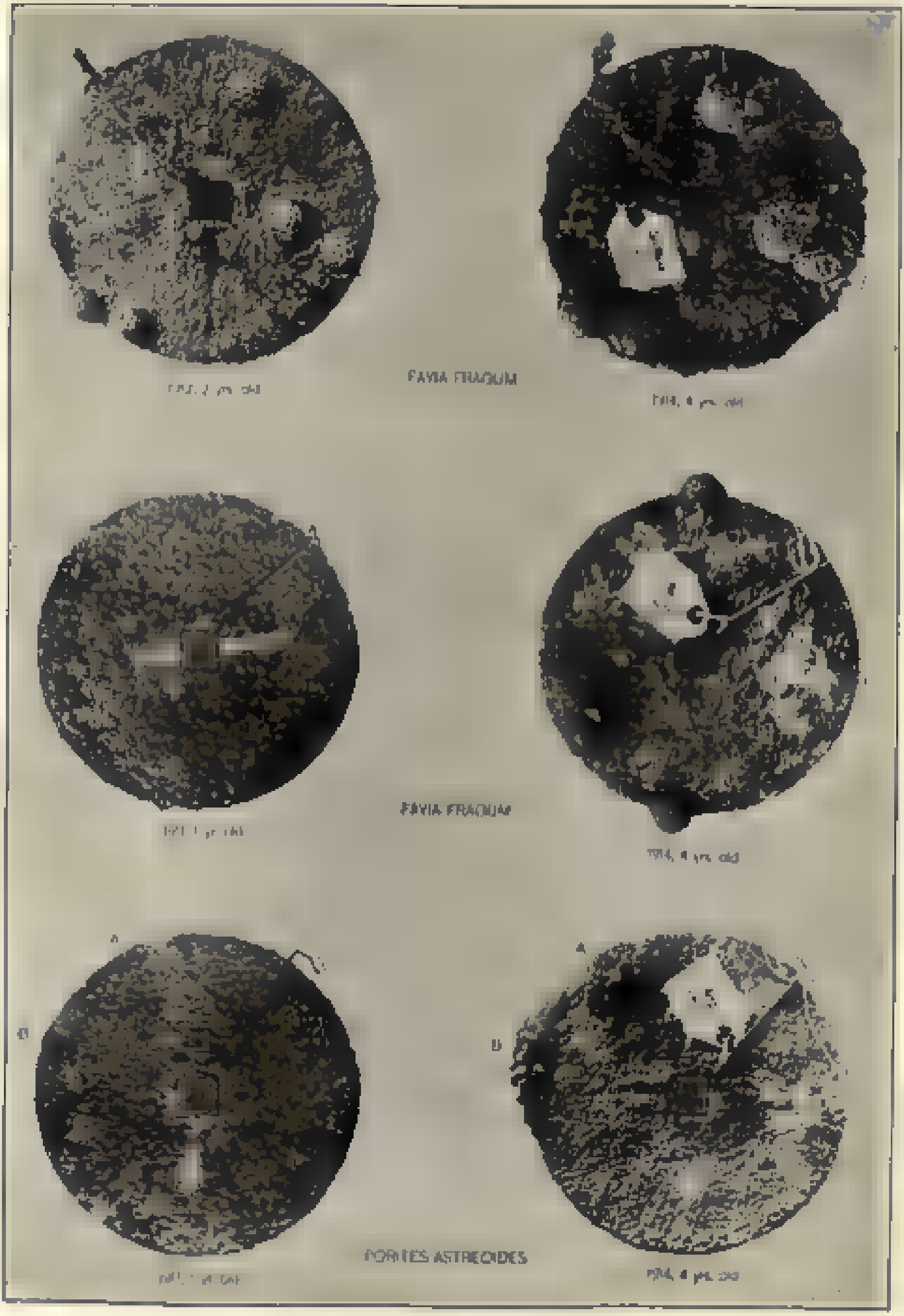
FIG. A. Live car with terra-cotta discs fastened to its bottom.

B. The same live car in the water after corals had been planted on its bottom.

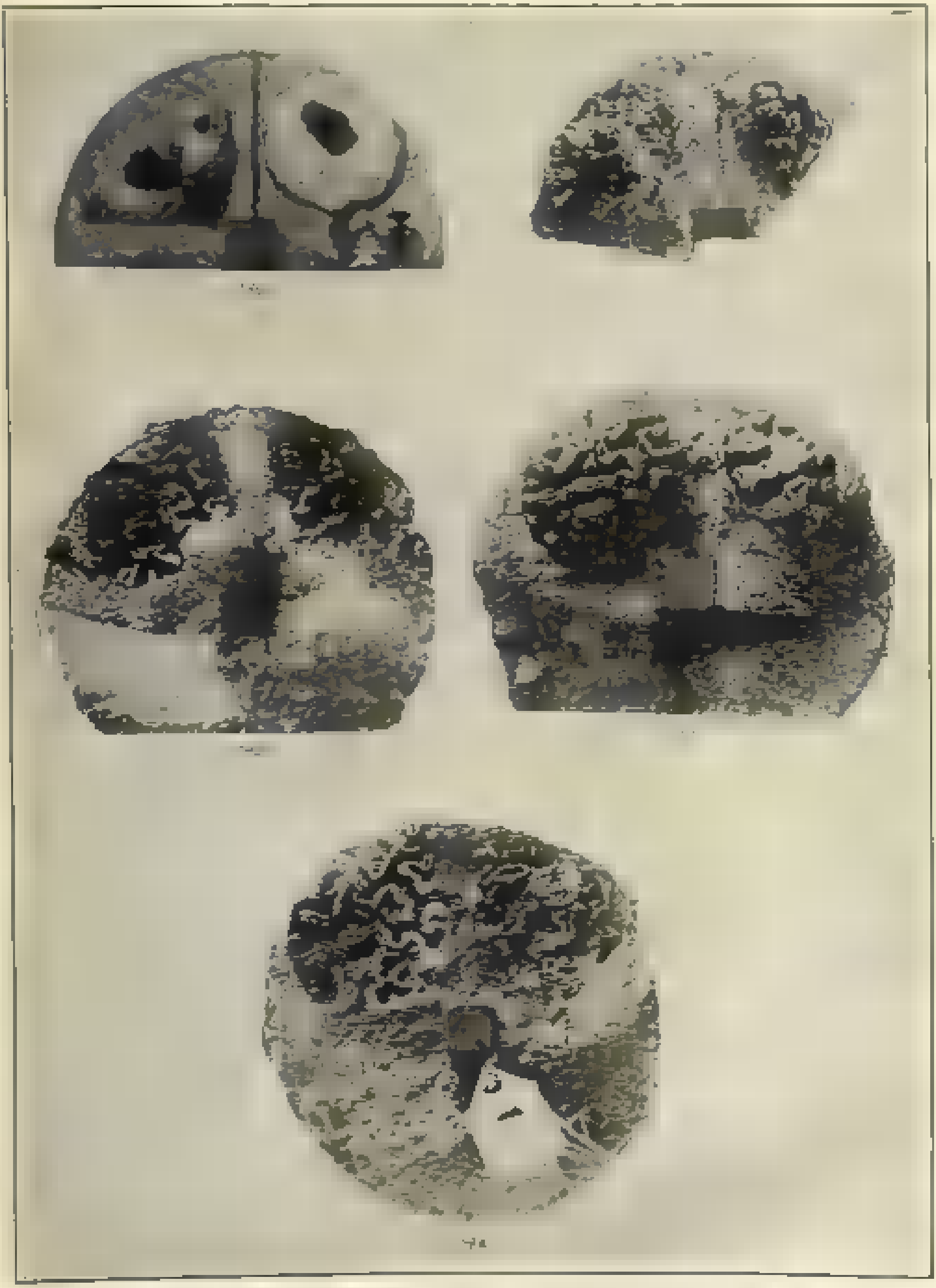
PLATE 21.

Corals reared from planulae.

Top row, *Favia fragum* (Esper), 2 years old and 4 years old.
Middle row, *Favia fragum* (Esper), 1 year old and 4 years old.
Bottom, *Porites astreoides* Lamarck, 1 year old and 4 years old.
Diameter of the discs, 8 inches.



CORALS REARED FROM PLANULAE.



MAEANDRA AREOLATA (LINNAEUS), SHOWING GROWTH BETWEEN 1910 AND 1914.

PLATE 22.

Growth rate of *Maeandra areolata* (Linnaeus) between 1910 and 1914. Diameter of the disc, 8 inches.

Plate 23.

Growth rate of *Porites porites* (Pallas) between 1910 and 1914. Diameter of the disc, 8 inches.

PORITES PORITES (PALLAS), SHOWING GROWTH RATE BETWEEN 1910 AND 1914.

PORITES FURCATA LAMARCK AND PORITES ASTREOIDES LAMARCK, SHOWING GROWTH RATE.

Plate 24.

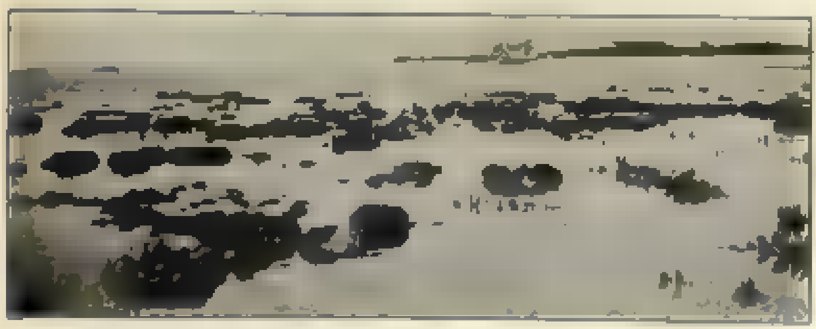
Growth rate of *Porites furcata* Lamarck, the tier on the left and the lower specimens on the disc of the tier on the right; and *Porites astreoides* Lamarck, the upper specimen of the right-hand tier. Diameter of the disc, 8 inches.

PLATE 25.

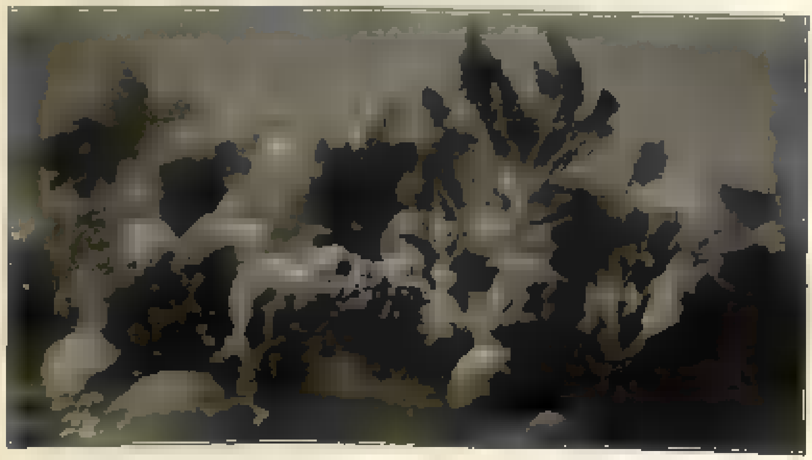
Growth rate of *Acropora muricata* (Linnaeus) between 1911 and 1914. Diameter of the disc, 8 inches.

ACROPORA MURICATA (LINNAEUS), SHOWING GROWTH RATE BETWEEN 1911 AND 1914.

A.



B.



C.

VIEWS OF THE FLORIDA CORAL REEFS.

PLATE 20.

Views of the Florida Reefs.

Figs. A, B. Two views of the reef on the west side of Loggerhead Key, Tortugas, as exposed at an unusually low tide on June 6, 1910. The massive, head-like corals are *Orbicella annularis* (Ellis and Solander); the whip-like objects are the gorgonian *Plexaura* sp.; the reticulated, fan-shaped corals are *Gorgonia flabellum* Linnaeus.

C. A view undersea of the reef at Carysfort Lighthouse, from a picture card. It shows *Orbicella annularis* heads and many waving gorgonians.

PLATE 27.

Skull Reef, outer barrier, Great Barrier Reef of Australia. After Saville-Kent.

SKULL REEF, GREAT BARRIER REEF OF AUSTRALIA.

CRESCENT REEF, GREAT BARRIER REEF OF AUSTRALIA.

PLATE 28.

Crescent Reef, outer barrier, Great Barrier Reef of Australia. After Saville-Kent.

267

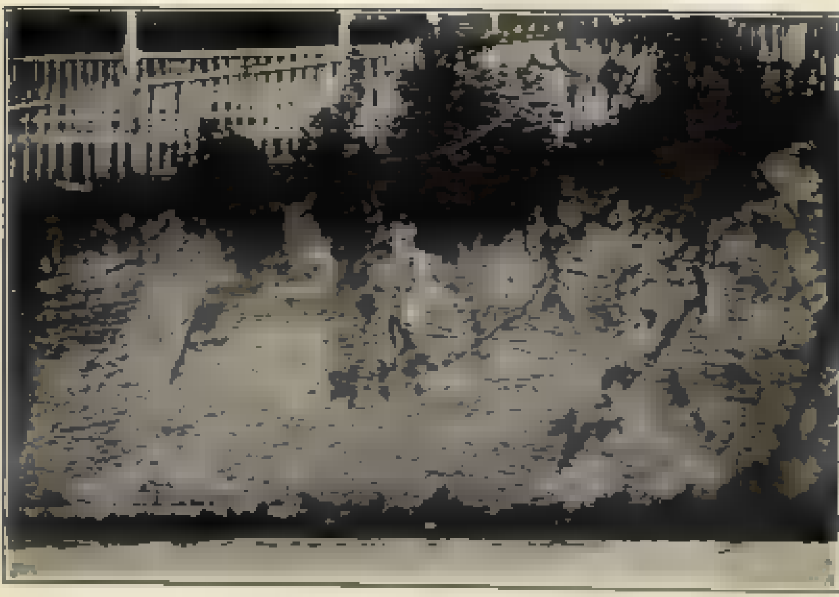
PLATE 29.

FIG. A. Wind-bedded siliceous sand, Cape Henry, Virginia.

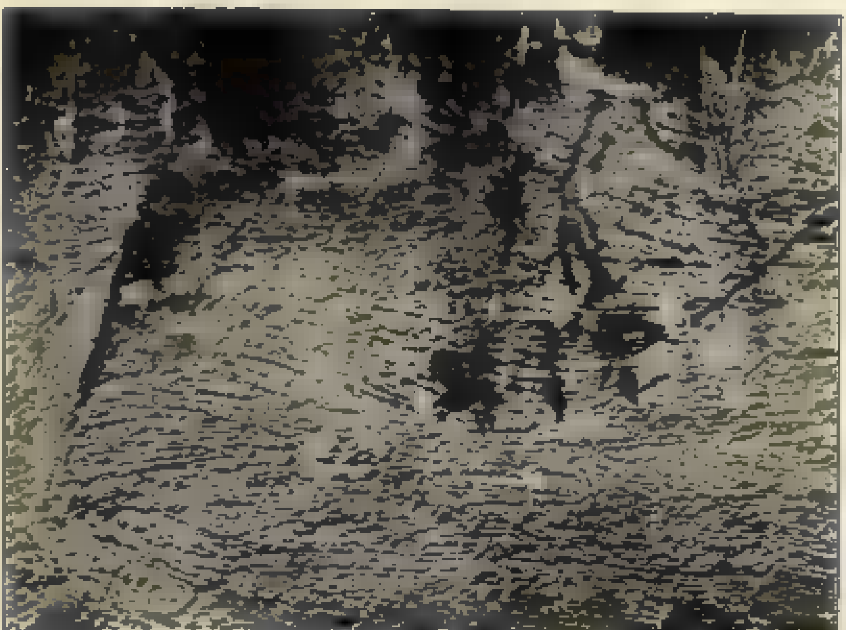
B. Wind-bedded, indurated oolite, near Morgan Bluff, Andros Island, Bahamas.

A. WIND-BEDDED SILICEOUS SAND, CAPE HENRY, VA.

B. WIND-BEDDED, INDURATED OOLITE, MORGAN BLUFF, BAHAMAS.



A.



B.

WIND-BLOWN OOLITE, NASSAU, BAHAMAS.

PLATE 30.

Wind-blown oolite, Nassau, Bahamas.

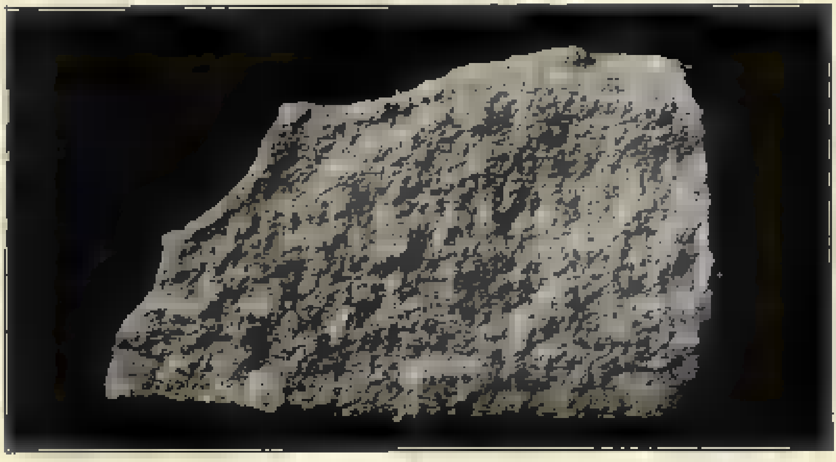
FIG. A. General view of an exposure along East Street.
B. A part of the same exposure on a larger scale.

PLATE 31.

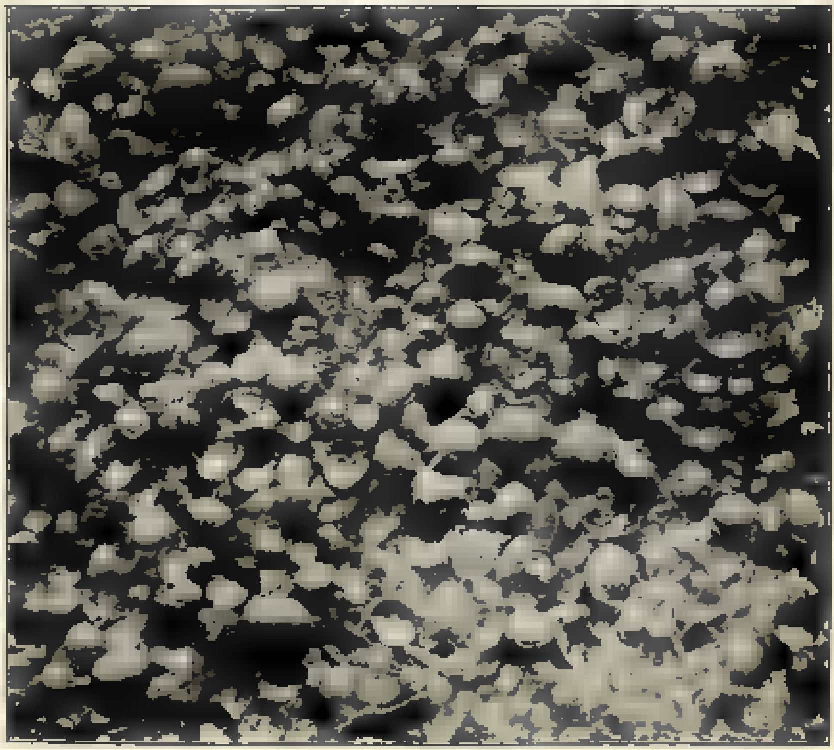
Bahamian marine oolite.

FIG. A. Surface of a specimen from Sharp Rock Point, South Bight, Andros Island, natural size.

B. A part of the same surface enlarged 10 times.

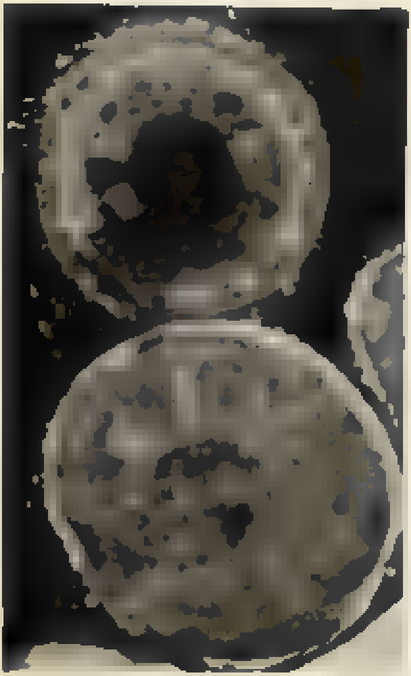


A.

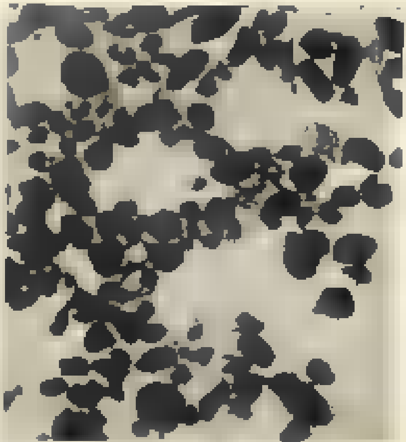


B.

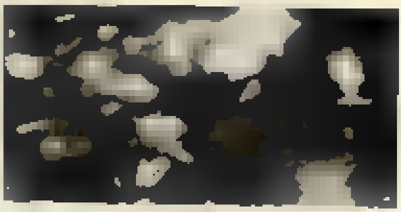
BAHAMIAN MARINE OOLITE.



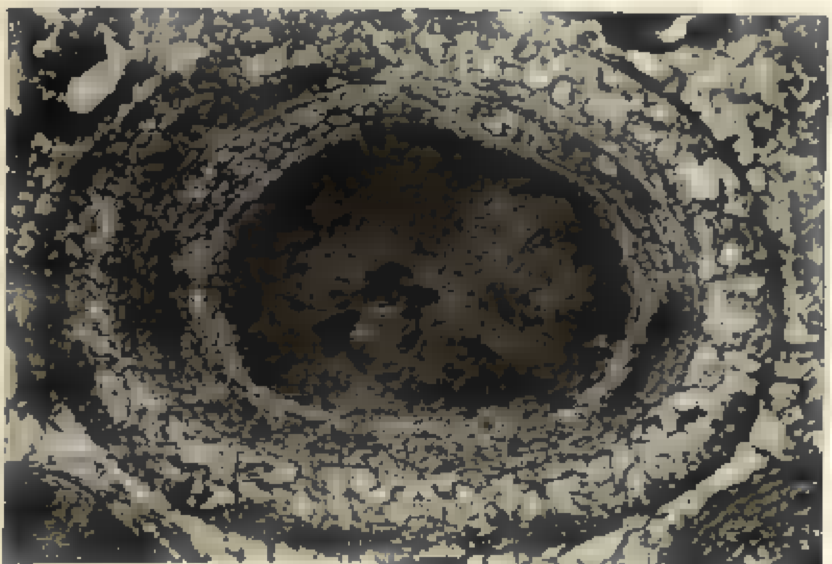
4 ×100



2 ×50



3 ×840



1 ×100

OOLITE GRAINS AND ARAGONITE NEEDLES.

PLATE 32

FIG. 1. Thin section of an oolite grain from the Bahamas, × 100.

2. Oolite grains in mud from the west side of Andros Island, Bahamas, × 30.

3. Aragonite needles in mud from the west side of Andros Island, Bahamas, × 940.

4. Thin section of oolite grains from Great Salt Lake, × 100.

PLATE 33.

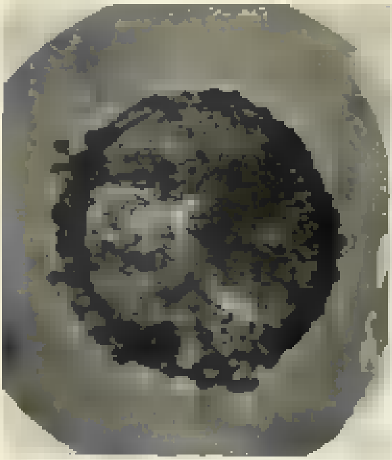
Artificially produced zonal spherulites of calcium carbonate.

FIG. 1. Spherulite produced through the periodic precipitation of calcium carbonate by adding ammonium carbonate to sea water, × 350.

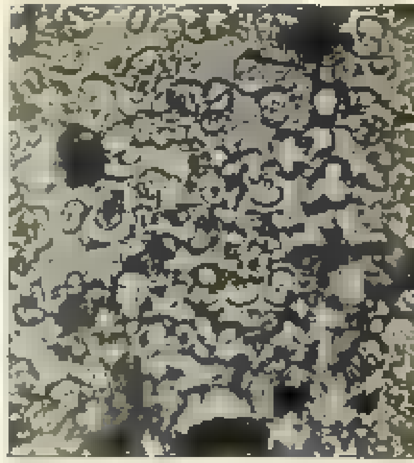
2. Other spherulites produced similarly to spherulite represented by fig. 1, × 700.

3. Spherulites formed through bacterial action on calcium acetate in Great Salt Lake water, × 50. Preparation by K. F. Kellerman.

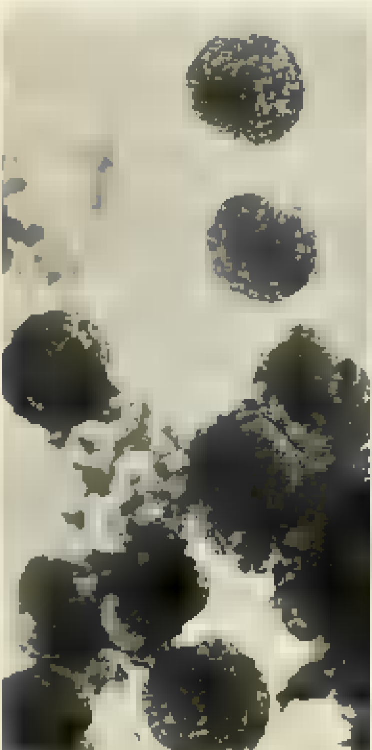
4. Spherulites bacterially formed in Great Salt Lake water, × 100. Preparation by K. F. Kellerman.



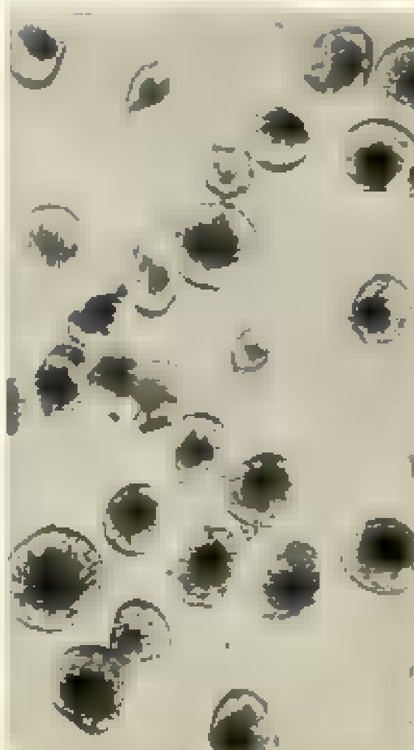
1 X 350



2 X 700



3 X 50

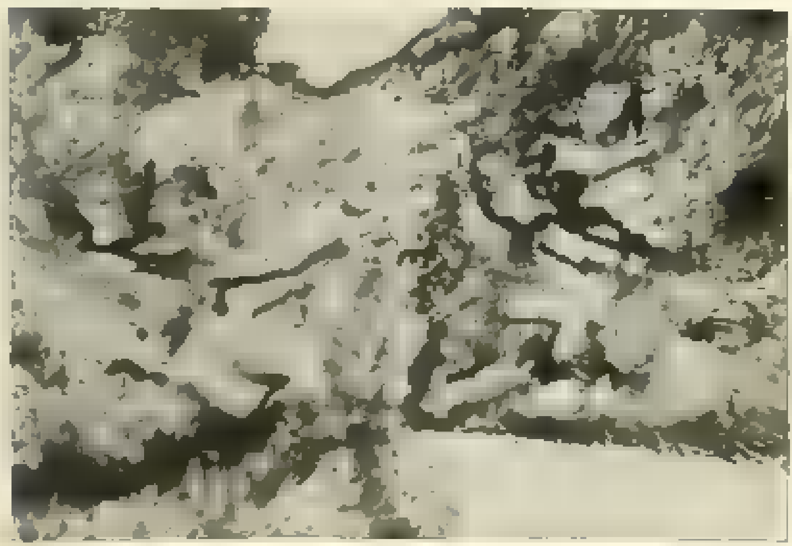


4 X 100

ARTIFICIALLY PRODUCED ZONAL SPHERULITES OF CALCIUM CARBONATE.

X 100

A.



B.

BORING FILAMENTOUS ALGAE.

PLATE 34.

Boring filamentous algae.

FIG. 1. Algal filaments left after decalcifying a corallite of *Orbicella cavernosa* (Linnaeus), × 100.

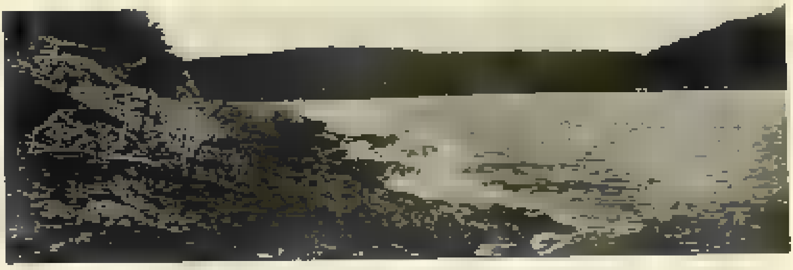
2. Thin section of a part septum of *Orbicella annularis* (Ellis and Solander) showing algal filaments in place. × 100.

PLATE 35.

West Indian shore lines of submergence.

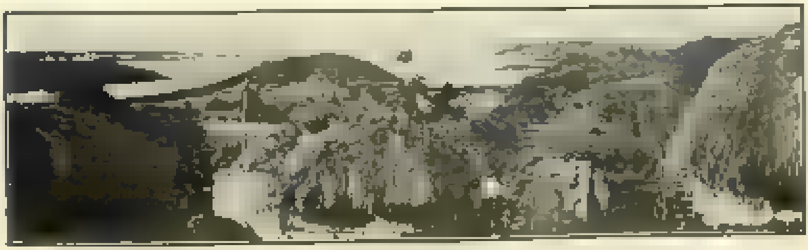
FIG. A. Looking seaward through the mouth of Santiago Harbor, Cuba.
B. Looking northward from the west side of the entrance to Santiago Harbor, Cuba.
C. Looking toward the head of Charlotte Amalia Harbor, St. Thomas.
D. Looking seaward from Mayer Village along Spencer Bay, Antigua.

A. LOOKING SEAWARD THROUGH MOUTH OF SANTIAGO HARBOR, CUBA.



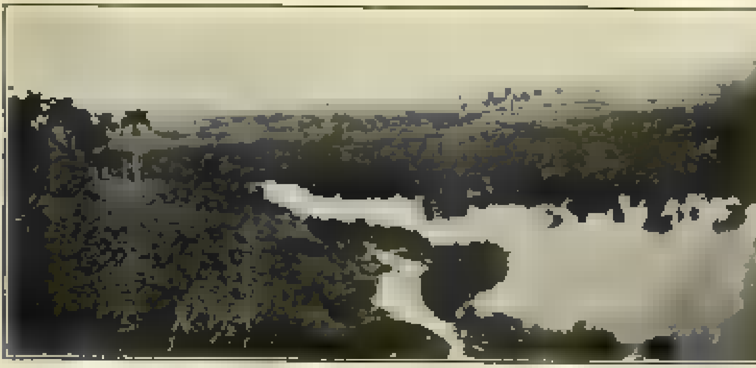
B. LOOKING NORTHWARD FROM WEST SIDE OF ENTRANCE OF SANTIAGO HARBOR, CUBA.

C. LOOKING TOWARD HEAD OF CHARLOTTE AMALIE HARBOR, ST. THOMAS.

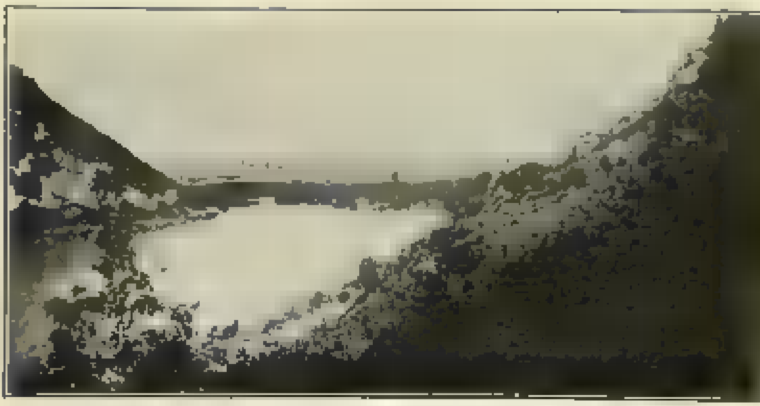


D. LOOKING SEAWARD FROM MAYER VILLAGE ALONG SPENCER BAY.

WEST INDIAN SHORE LINES OF SUBMERGENCE.



A. BASIN ABOVE THE GORGE OF THE RIVER.



B. UPPER END OF THE GORGE LOOKING TOWARD THE BASIN.

C. VIEW UPSTREAM FROM THE LOWER END OF YUMURI GORGE.

VIEWS OF THE BASIN AND GORGE OF YUMURI RIVER, MATANZAS, CUBA.

PLATE 38.

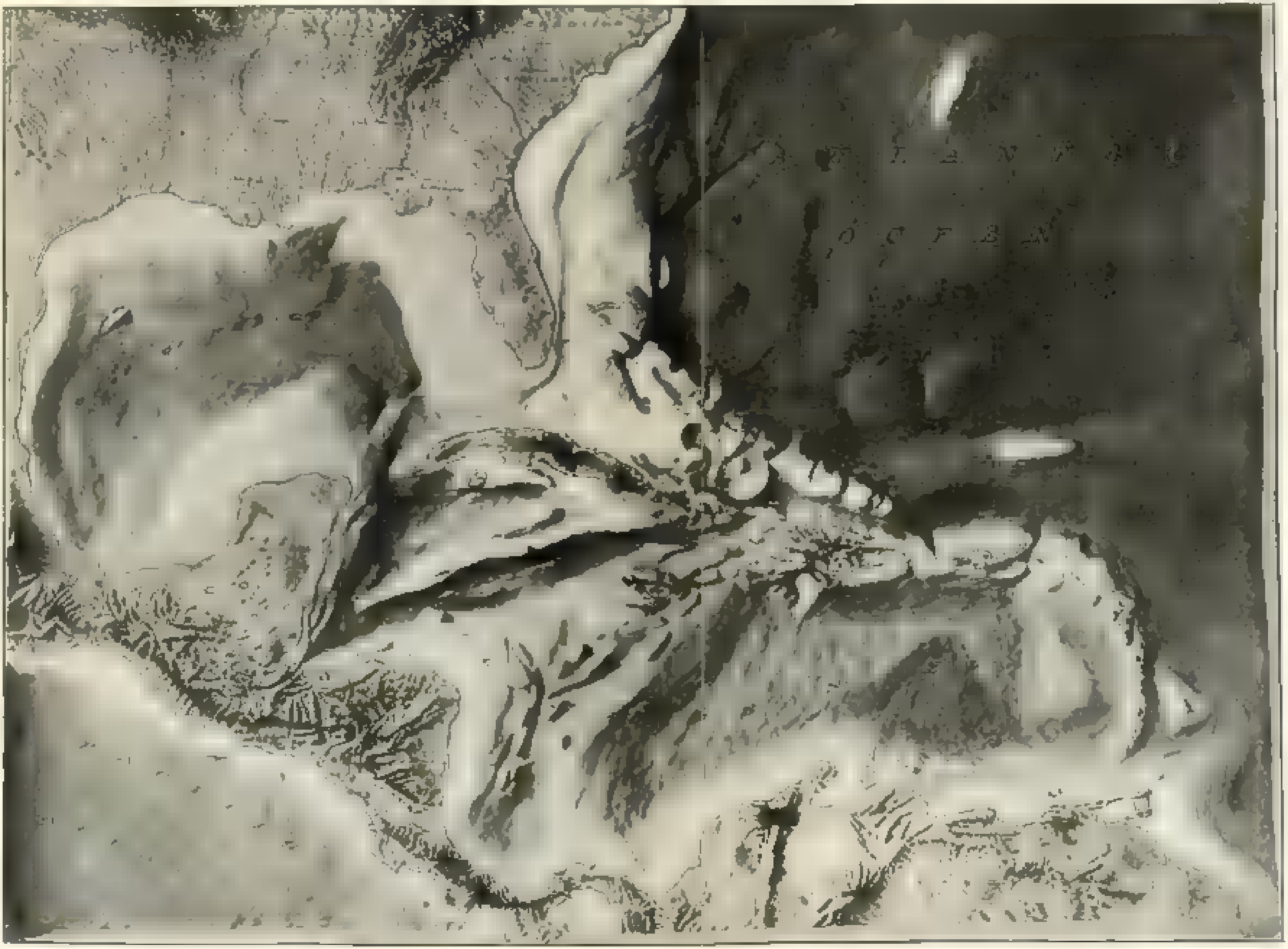
FIG. A. Hill-rimmed basin above the gorge of Yumuri River, Matanzas, Cuba.

B. Upper end of Yumuri gorge looking toward the basin.

C. View upstream from the lower end of Yumuri gorge. If this basin were depressed between 50 and 100 feet a pouch-shaped harbor with a narrow entrance would result.

PLATE 37.

Model of the Gulf of Mexico and the Caribbean Sea. (Made for the U. S. Coast and Geodetic Survey by E. E. Howell.)



MODEL OF THE GULF OF MEXICO AND THE CARIBBEAN SEA.

THE CORRELATION OF THE QUATERNARY DEPOSITS OF THE BRITISH ISLES WITH THOSE OF THE CONTINENT OF EUROPE.

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INTRODUCTION.

In any attempt to reconstruct the geographical and meteorological conditions of various stages of a former period, it is necessary first to classify the various deposits which are referable to the period into definite stages. This preliminary is often difficult; in the case of the Quaternary deposits of the British Isles it is especially difficult because of their great complexity. It is hard to find fixed characters to act as a means of correlating the various local facies one with another, and to distinguish slight oscillations of the ice-edge from longer periods of interglacial rank. It is necessary to find some district outside these islands where the succession is simple and the amount of field work done sufficiently great to make the conclusions arrived at fairly certain. Such a district exists in the north German plain which was visited only by ice from Scandinavia, unmixed with local ice, which lay in the region of deposition of that ice, and which possesses a literature of truly stupendous proportions. In fact, it was only when I began to collect a bibliography of the subject that I realized the magnitude of the task I had undertaken.

This study of north Germany gave me a series of very definite glacial and interglacial horizons, which could be traced by ordinary stratigraphical and paleontological methods through Holland, and correlated with fair certainty with the glacial deposits of eastern England. But in Holland the Rhine gravels entered into the series, and could be traced through the Vosges and Plateau Central into the river valleys of western France. The Rhine gravels had been traced upstream and connected with the Alpine glacial sequence made out by Penck and Brückner, which Penck had extended to the Pyrenees, where it was connected with the gravels of the Garonne. The sequence in the Seine and Somme is exactly similar to that in the Thames, and the two could be correlated directly. In short, a network of cross correlations could be made between the various districts, reducing the chances of error to a minimum.

For these reasons the present paper includes the whole of northern Europe. Of course it was not possible to make a complete study of the Quaternary literature of Europe, which can not fall far short of a hundred thousand papers, etc., in more than a dozen languages. The working bibliography actually collected numbered several thousand entries, but the references cited in this paper include most publications of importance bearing on the subject.

There are a few points of detail arising in connection with the correlation which may be briefly referred to. The first is the color of deposits. W. O. Crosby (1)[1] found that in the northern United States and Canada the soils are almost universally brownish or yellowish, but not red, except where they result from the disintegration of a red rock. On the other hand, in the southern United States, the red color greatly predominates over browns and yellows, and in the West Indies and South America the redness of the soil is even more intense and universal; the red lateritic aspect of soils in the Tropics is well known. The difference is more or less distinctly observable in all longitudes and in both Northern and Southern Hemispheres. The brown, yellow, and buff colors of northern soils are due to the presence of yellow ferric hydrates like limonite; the red color of southern soils, though usually attributed to hematite, is probably mostly due to the red ferric hydrate turgite. This difference depends not on underlying rocks but on climate. Crosby continues:

> Ferric hydrate, the coloring agent of northern soils, is dehydrated at the temperature of boiling water, and it seems probable that a partial, if not complete, dehydration may result at much lower temperatures, if unlimited or geologically long time is allowed.

In the Southern States the red color is only superficial, extending to a depth of 2 to 10 feet, and passing through orange and gray to the natural color of the rock. Thus the redness of a soil depends both on its age and the temperature at which it was deposited, and in this we find a cause of the red color of many very old bowlder clays, noted and used as a means of correlation by F. Leverett (2), J. van Baren (3), C. Gagel (4), and others in opposition to the prevailing blue-gray color of later bowlder clays, weathered brown at the surface. In extremely calcareous old clays like the chalky bowlder clay of East Anglia this rule does not hold, but the disintegration of the granitic rocks forms an equally reliable index of age. Erratics of granite in the chalky bowlder clay of Hertfordshire and Finchley frequently fall to a granitic sand at a touch, though they must have been sound when they were incorporated in the ground moraine. The same state of decay has been noted in the granitic pebbles of the

[1] Numbers in parentheses refer to bibliography at end of paper.

oldest bowlder clay of Europe. On limestone slabs the fossils frequently stand up in marked relief owing to the same cause.

The colors of fluviatile and littoral sands and loams which are frequently exposed to the air during their formation, show a similar variation from red in the tropical to yellow or brown in temperate regions, which is attributed by Barrell (5) to the degree of oxidation undergone. This variation of color extends into the polar regions, where the prevailing tint is gray, owing to the scarcity of organic iron coloring matter as well as the slight degree of oxidation. The detrital deposits such as "head" and the granitic loam of Ballybetagh in Ireland show also a prevailing gray tint. Accordingly, a gray deposit without fossils is of itself strong evidence for a severe climate during its formation; when fossils do occur in such a gray deposit, as in the gray sands of Ulster and the gray silts of the Isle of Man, they are generally of arctic types.

The relations of the coarseness of fluviatile deposits and the grade of rivers have also been worked out by J. Barrell (5). An arid climate tends to increase the ratio of coarse to fine material and the freshness of the fine even where the land relief leads to vigorous erosion. A decrease in the temperature acts very strongly in the same direction as aridity, by weakening the power of vegetation to produce decay but prevent erosion, and by increasing the amount of frost action. Increased snowfall, however, works in the opposite direction by protecting the surface from denudation and producing transportation. For these reasons waxing glacial conditions are normally associated with terrace formation in the neighboring river valleys; waning glacial conditions with erosion.

On the seaward ends of great rivers the question is further complicated by oscillations of the relative level of land and sea. The terraces here are sometimes attributed to one cause, sometimes to the other: probably in most cases both acted together, for the terrace-building effect of waxing glaciation seems usually to have been prolonged into the waning period of glaciation by an isostatic depression due to the weight of the ice, as in the *Cyprina* clays and Holderness marine beds terminating the first glacial period, the 100-foot beach terminating the second, and the *Yoldia* clays terminating the third. The possibility of terrace-forming in a warm climate, however, makes further criteria necessary, such as large blocks, northern organisms, or passage into a moraine.

Marine terraces on rocky coasts seem only to be formed when the relative level of the land and sea remains unchanged for a considerable time. When the levels are varying rapidly, noticeable raised beaches are not necessarily developed. This suggests a reason for a rather puzzling fact which will be noticed in the descriptions of

England and Ireland, namely, that a raised beach of a definite age, after extending fairly continuously at a nearly uniform height for perhaps a hundred miles, disappears abruptly even on a coast suitable for its preservation. The weaker parts of the crust where most of the bending occurs are likely to prove most unstable, so that on them the sea rarely stays long in one position, and raised beaches are not developed.

I do not propose to enter into a discussion of the value of plants and animals as climatic gauges or for correlation. Suffice it that as their present distribution is undoubtedly governed principally by climate, either present or not long past, so must their former distribution. The use I have made of them for correlation is seen in the individual cases; only the facies is employed save where a species is definitely characteristic of a certain horizon, such as *Corbicula fluminalis* and *Paludina diluviana* in the older interglacial. The "Chellean fauna," characterized by the coexistence of *Elephas antiquus* and *E. primigenius*, with *Hippopotamus major* and other large Quaternary mammals, is a very useful facies for correlation.

A means of correlation which proved somewhat disappointing was the sequence of archeological stages. The Acheulian horizon especially seems to be vague, for it overlaps or grades into the Chellean on the one hand and the Mousterian on the other, and it appears to occur both before and after the second glaciation of England and north Germany. In general, the relations of the stages appear to be as follows:

Cold period:	Pre-Chellean.
Warm period:	Chellean Chelles-Acheulian.
Cold period:	Acheulian-Mousterian.
Warm period:	Mousterian.
Cold period:	Aurignacian. Solutrean. Magdalenian.

This is based on the sequence of faunas associated with the implements as described by many authors.

1. THE NORTH GERMAN PLAIN IN THE GLACIAL PERIOD.

The whole of the evidence as to the succession of stages in the north German plain was summarized in 1913 by C. Gagel (6), who finds undoubted proof of a plurality of glaciations. His chief lines of evidence are:

1. The occurrence in many places of beds of ground moraine, separated by extensive fluvio-glacial deposits and connected with others which are grouped into terraces of very different heights above the present streams. Between the formation of these different terraces very deep and energetic erosion is demonstrable.

2. The various moraines and fluvio-glacial terraces differ extraordinarily both in their morphological form and in the depth to which they are weathered, varying from quite fresh moraines with unaltered surface forms and a very slight degree of weathering, associated with equally slightly weathered fluvio-glacial gravels, to old "senile" moraines, with forms so strongly denuded as often to be unrecognizable, associated with very deep-going and generally intense weathering, both in the moraines and in the gravels.

3. Between the various groups of moraines and fluvio-glacial sediments are often found extra-glacial deposits containing remains of warmth-loving faunas and floras which according to our present experience can not have lived at the edge of a continental ice sheet.

As an example he compares the very worn moraines of Schleswig-Holstein, the Elbe Valley, and Silesia, weathered to a depth of 10, 12, and even 20 meters, with the rough, fresh looking moraines of the Baltic Hohenrücken, weathered to a depth of only 1.25 to 1.75 meters. The former are deeply weathered, even where they pass under the latter, and are often separated from them by deposits indicating a temperate climate. Gagel remarks that it is difficult to escape from the conclusion that the weathering of the one, 10 to 20 times as deep as the other, must have required 10 to 20 times as long. After a critical examination of all the interglacial deposits known to him, being 22 marine and 114 lacustrine interglacial deposits and 45 zones of weathering, he finds them all referable to two important characteristic horizons, which are shown at seven places by direct superposition in the same section and at five places by undoubted stratigraphical correlation in closely neighboring sections. In the younger horizon the marine deposits always underlie the lacustrine, in the older horizon they overlie them, indicating a considerable sinking of the land in the middle glacial period. Gagel has therefore no hesitation in adopting the hypothesis of a threefold glaciation of Germany by ice from the north. Of these the oldest was the most extensive and the youngest the least so, and he correlates them with the Mindel, Riss, and Wurm glaciations of the Alps. He finds no equivalent of the Gunzian glaciation, and in the terraces corresponding to the first interglacial of the Alps there is no northern material.

The type sections of this series are those near Berlin, at Rixdorf, and Phoeben. The section at Rixdorf is as follows:

5. Upper bowlder clay.
4. Thick diluvial sands.
3. Bed of coarse gravel with remains of large mammals.
2. Middle bowlder clay.
1. Paludina bed with *P. diluviana*.

The mammal remains are so numerous and so well preserved that they can not have been transported far. They consist of *Elephas primigenius* (abundant), *E. trogontherii*, *E. antiquus* (one tooth), *Rhinoceros tichorhinus* (abundant), *Rh. Merckii* (one tooth), *Bos primigenius*, *Bison priscus*, *Equus caballus*, *Cervus alces*, *C. elaphus*, *C. euryceros*, *Rangifer groenlandicus*, *Ovibos moschatus*, *Canis lupus*, *Ursus*, etc.—a temperate fauna with a few high-northern elements.

A number of borings in the neighborhood show, on the same stratigraphical level and nearly on the same absolute level as the Rixdorf horizon, between two bowlder clays, peat beds with grasses and pine remains. Further, the corresponding interglacial of Phoeben and the considerable interglacial weathered zone of Glindow belong stratigraphically to the same horizon and contain a different *Paludina* (*P. Duboisiana*) to the true *P. diluviana*, which was found at Rixdorf about 50 meters deeper.

The lower interglacial with *P. diluviana* is very rich in Mollusca, including *Bithynia tentaculata* and *Dreissensia*. Often it is an almost pure shell bed, from 2 to 20 meters thick, lying with great regularity at 0 to 10 meters. It is an old sea floor with abundance of life indicating favorable conditions.

Very numerous borings round Berlin leave not the slightest doubt as to the succession—the *P. diluviana* bed lies always under a thick bowlder clay which is overlain by a second interglacial, the Rixdorf horizon, and very often it lies above a still deeper bowlder clay.

The next section described is that of Phoeben, west of Potsdam, where the younger interglacial is found between bowlder clays as a sandy peat with a mammalian and molluscan fauna, the latter including *P. Duboisiana*, *Planorbis albus*, and *Belgrandia*. Below the bowlder clay underlying this bed have been found in borings the lower *Paludina* bed with *P. diluviana* and temperate plants, and below this again still older bowlder clay.

A similar succession is seen at several points in Schleswig-Holstein, especially Süderstapel, Hamburg, and Lauenburg. The succession at Süderstapel is important because under bowlder clay, weathered to a depth of 10 meters and thus older, is a shell bed with "great round mussels," probably the Eem bed (*Tapes aureus eemiensis*). This is underlain by the black Lauenburg clay, a persistent horizon overlying the oldest bowlder clay of Schleswig and Holland. The upper part of the section is formed by peat with temperate plants overlain by fresh bowlder clay.

In Hannover is the famous section of Luneburg, with a voluminous literature of its own, which is now generally considered to show three glacial horizons separated by interglacial deposits.

This important paper of C. Gagel's has since been confirmed and extended by a survey by H. Menzel (7) of all the important occur-

rences of land and fresh-water Mollusca in glacial and interglacial horizons in Germany. He finds that the various molluscan faunas of older Quaternary age can be divided into cold-loving and warmth-loving groups, whose distribution shows that even in the unglaciated region of southern Germany an arctic climate prevailed during the glacial periods. In north Germany the glacial faunas are found chiefly in gravels, in south Germany in loess and sand loess. True interglacial Mollusca occur on two horizons of different age, separated by glacial deposits. The older one is characterized by *P. diluviana*, *Bithynia tentaculata*, and *Dreissensia polymorpha*, the younger by *P. Duboisiana*, *Belgrandia*, and *Planorbis albus*.

In West Prussia the lower interglacial age of the marine *Cardium* and *Cyprina* clays and Eem beds is confirmed by the occurrence in them of *Dreissensia polymorpha* and *P. diluviana*. In Posen *P. diluviana* has been found in interglacial deposits associated with *Corbicula fluminalis*, and these two have also been found associated near Odessa and as derived fossils in the middle bowlder clay of East Prussia.

A. Penck (8) was the first geologist to bring forward evidence in support of a threefold glaciation of the district. Since 1880 a number of other more or less successful attempts at classification have been made, the net result of which is very much in favor of Gagel's classification into three glacial and two interglacial horizons (9).

GLACIAL SUCCESSION IN THE RIVER VALLEYS.

Detailed consideration of the glacial succession in the valleys of the north flowing rivers south of Berlin is not necessary, as the conditions are essentially similar to those of the Alps.

The deposits of the Weser Valley, studied by O. Grupe (10) and L. Siegert (11), may, however, be considered here, as they differ considerably, and the differences illustrate the scheme of classification. According to Grupe, the valley of the Weser originated in middle Pliocene, and was cut to a depth of at least 25 meters below the present level of the river. The process of erosion left "Old Pliocene" gravels at a height of 120 to 160 meters above valley level. In late Pliocene times the valley was partially filled by clays and sands containing *Mastodon arvernensis* and *M. Borsoni*. Belonging to the Quaternary there are three gravel terraces—upper, middle, and lower. The upper terrace interdigitates to the north with deposits of the first glacial period on the Porta River, and is accordingly contemporaneous with this period. This was the maximum glaciation in the district and, correspondingly, the upper terrace reaches the great thickness of 60 to 70 meters at Hameln. The lower part of the middle terrace includes at Nachtigall, peat with *Corylus avellana*,

and also contains a fauna of large diluvial mammals (*Bos primigenius, Cervus elaphus, Equus caballus, Elephas primigenius, Rhinoceros tichorhinus, Ovibos moschatus*) which is very similar to the fauna of the Rixdorf horizon in the Berlin region, and appears to be of the same age. The lower part of this terrace is thus evidently interglacial, but the upper part contains a molluscan fauna which, according to Menzel, is of Arctic type, and thus represents the succeeding glacial period, and Grupe finds that this terrace interdigitates to the north with moraine formations of the second ice sheet at Hameln. The third ice sheet did not extend into the region of the upper Weser Valley dealt with by Grupe, but as Stoller found that in the lower Weser Valley the lower terrace (up to 5 meters) was deposited during the glaciation by this ice sheet, and derived part of its materials from its moraines, Grupe considers that the lower terrace on the Weser at Hameln also corresponds to the third glacial period, though a peat layer at its base shows that the formation of this terrace also commenced during the preceding interglacial period.

Siegert's conclusions are quite different. He was unable to confirm the existence of a high terrace 70 meters thick, but found instead a much thinner terrace with northern material, overlain from Hameln downstream by a thick series of banded clays, marl sands, ground moraine and end moraines of the second glaciation. Older than the high terrace are remains of the glacial formations of the first glaciation of the district, and still older, higher Weser terraces of local materials only. The Weser "high terrace" thus dates from the first interglacial period, and Grupe was in error in stating that it interdigitates with the moraines of the first glacial period.

The lower part of the middle terrace, with its temperate fauna and flora, thus corresponds, not with the first interglacial, but with the second, and the upper part, with the arctic mollusca, with the third glacial period. The low terrace, Siegert therefore places in the postglacial period.

In deciding between these conflicting age determinations, it seems safe to place the mammal deposit in the lower part of the middle terrace on the same horizon as the Rixdorf mammal bed of Berlin, i. e., in the second interglacial, which confirms Siegert's view of the age of the high and middle terraces. On the other hand, there is no reason to reject Stoller's conclusion that the low terrace of the Weser west of Luneburg also belongs to the third glacial though to the concluding stages of it. This refers both middle and low terraces to the third glacial, separated by a period of erosion and improved climate corresponding to the Baltic interstadial, to be described later. This seems legitimate, for a climate allowing the growth of small

trees in the south Baltic regions would certainly allow the formation of peat southeast of Brunswick.

The latter view is supported by the mode of occurrence of the loess referred to later. It is sufficient to remark here that in the south Baltic region loess occurs on the outer moraines of the last glaciation, preceding the Baltic interstadial, but not on the inner moraines, succeeding that interstadial. Correspondingly, in the upper Weser Valley, loess, weathered to a depth of 2 to 4 meters, occurs on the higher and middle terraces, but not on the lower terrace. For this reason Grupe places it in the last interglacial, and Siegert in the late glacial period, while its true position, as in the Baltic, would seem to be interstadial. We may therefore summarize the conditions in the Weser Valley as follows:

Postglacial: Alluvium.

Third glacial period: Post-interstadial, lower terrace. Interstadial, loess; peat at base of terrace at Hameln. Pre-interstadial, middle terrace, upper part.

Second interglacial: Lower part of middle terrace. Peat, etc., of Nachtigall with *Corylus avellana*. Mammal fauna of base of gravels.

Second glacial: Banded clays, marl sands, ground moraine and end moraines from Hameln downstream. Upper part of Weser high terrace.

First interglacial: Lower part of Weser high terrace with northern material.

First glacial: Remains of glacial formations older than high terrace.

Preglacial and Pliocene: Weser higher terraces, formed of local materials.

THE BALTIC INTERSTADIAL.

The end moraines known as the Baltic Hoheurücken have been, as by the late J. Geikie, referred to a fourth glaciation, but hitherto all attempts to find deposits referable to the corresponding interglacial have failed. Fossiliferous deposits intercalated in the upper bowlder clay are known, and are fairly common in East Prussia, but the fauna and flora are in every case of an arctic or subarctic type, such as could well have lived in close proximity to the ice margin. These fossiliferous deposits were investigated by E. Harbort in 1910 (12), the Mollusca and plants being described by H. Menzel and J. Stoller. The fauna indicates "arctic" but not "polar" conditions, all the species extending south into the tree zone; the plants indicate a July temperature of at least 10° C. and a vegetation period of three to four months with a temperature of 3 to 6° C. Harbort considers the oscillations to have been slow and irregular, ice free periods lasting sometimes for decades and possibly centuries before the peat deposits and small trees were buried by a readvance.

Similarly no interglacial can be proved older than that with *Paludina diluviana* and *Tapes aureus eemiensis*, nor do the older river terraces which should correspond with this interglacial bear

northern material. Zache (13) remarked that among the Tertiary sands in Brandenburg are bowlders and sands of northern material in a few places, possibly representing a still older glaciation, but so far as I am aware this is unconfirmed.

ARCHEOLOGICAL PERIODS.

The correlation of these three glacial periods with the archeological stages is still somewhat uncertain. In 1910 R. R. Schmidt (14) placed the Aurignacian stage in the postglacial period, and in 1913 the same author (15), with the assistance of E. Koken and A. Schliz, made an elaborate attempt to correlate the diluvial stages with the archeological sequence mainly on the basis of cave explorations in Swabia (southwest Germany). He finds that the Mousterian, Aurignacian, Solutrean, Magdelenian, and Azilian-Tardenoisian stages follow immediately one upon another, with no break or hiatus; the accompanying diluvial fauna shows that below the Mousterian and at the beginning of the Magdalenian are two beds with high-arctic rodents, indicating two deteriorations of climate. He considers that there is no room for an interglacial between these two arctic beds, so that the Mousterian belongs to the maximum of the Würm glacial period, and the Magdalenian to the Bühlstadium. Gagel, however (review in Geologisches Centralblatt, vol. 20, pp. 449–451), points out that this correlation is invalidated by the erroneous age determinations of some beds in the north German diluvium, e. g., an interglacial bed at Markleeberg, near Leipzig, ascribed to the last interglacial period, undoubtedly belongs to the first. This error was also pointed out by F. Wiegers in 1913 (16), who found Mousterian implements in a calcareous tufa at Ehringsdorf, associated with *Elephas antiquus* and a warm fauna, and therefore interglacial.

Gagel describes (17) from a bowlder sand in West Holstein flint implements apparently of early neolithic type (ax, scraper, thin, long knife, etc.). The implements are in situ 40 to 60 centimeters deep in bowlder sand lying on upper bowlder clay at Michaelisdonn; although they lie among well-rolled pebbles they are quite sharp angled. If the age determination is correct, it carries the neolithic period back into the last glacial period.

In 1913 (18) Gagel also summarized the facts which throw light on the position of the paleolithic stages in the glacial sequence. Practically the only definite horizon is that given by the very characteristic knives of the Levallois stage in the younger Acheulian, which have been found in association with interglacial deposits at Hundisburg near Neuhaldensleben, northwest of Magdeburg, in Saxony (by Wiegers) and near Leipzig. At Hundisburg the implement bed contains also an interglacial fauna of snails, mussels, and great diluvial mammals. Above this lies a bowlder clay covered by an important

stone bed indicating energetic erosion and denudation; above this lies a loess bed which we must consider as the æolian equivalent of the last glaciation, so that the bowlder clay lying discordantly beneath it must belong to the middle glaciation and the implementiferous bed underlying the bowlder clay to the first interglacial.

Near Leipzig, in a region to which the last glaciation did not reach, there have recently been found numerous paleolithic implements, including the characteristic Levallois knife, in sand and gravel beds associated with mammalian remains. These beds are overlain by typical bowlder clay, which, as this district is certainly outside the limits of the last glaciation, can only be the moraine of the middle glaciation, so that the implements must come from the first interglacial of north Germany.

In 1912 the same conclusions were reached by J. Bärtling (15) from finds of implements in Westphalia. In addition to those referred to by Gagel and already quoted, he mentions that Wiegers found a well-shaped artifact classed as Mousterian in the lower beds of the last interglacial in the Rhein-Herne Canal; the conditions of its deposition point to its being in situ.

If now we correct Schmidt's scheme of correlation in accordance with these age determinations, we find that the lowermost of his arctic rodent beds, underlying the Mousterian, represents the middle glaciation of north Germany; the upper rodent bed and consequently the beginning of the Magdalenian period, then fall in the maximum of the last glaciation and not in the Bühlstadium. This has the merit of agreeing with the correlation which Penck and Bruckner worked out for the Alpine region.

SUMMARY.

Lower bowlder clay.—Very deeply weathered. Ice reached its maximum extent at least in the west and southwest and possibly over the whole area. Higher ("chief") terrace of the rivers.

First interglacial.—*Cyprina* clays. Eem beds. Beds with *Paludina diluviana*, *Corbicula fluminalis*, *Bithynia tentaculata*. Acheulian culture.

Middle bowlder clay.—Weathered to a depth of 10 to 12 meters. This glaciation may have overstepped the limits of the preceding one at a few points. Middle terrace of the rivers. Mousterian culture.

Second interglacial.—*Corbicula Duboisiana.* Rixdorf horizon. Mousterian culture.

Upper bowlder clay.—Weathered to a depth of only 1 to 2 meters. This glaciation nowhere overstepped the limits of the preceding one, but was of considerably less extent. Magdalenian culture.

Baltic interstadial.—Arctic marine and fresh-water deposits of East and West Prussia.

Baltic readvance.—Moraines of the Baltic Hohenrücken.

2. THE LOWER RHINE VALLEY AND HOLLAND.

The best basis for correlating the glacial beds of Holland with those of north Germany is given by the Eem zone, which in northwest Germany has been shown to fall in the interglacial between the lower and middle bowlder clays. The same bed has been described from borings at a few points in Holland, and its relations with the other members of the Quaternary series made out.

The Eem zone was found by Dubois in borings in 1903 underlain by bowlder clay representing the maximum glaciation of Holland; this was confirmed by Lorié (19) in 1905 and 1906.

In the region north of the Rhine, and south and east of the Zuyder Zee, investigations have been carried out by J. van Baren (20). Two bowlder clays were found, an upper gray bowlder clay and a lower red, sandy bowlder clay of a lateritic aspect. The red color of the latter was shown by G. Leopold (21) to be due to intense weathering; the gray clay is much fresher. The red clay occurs over the whole of the region of Veluwe west of the Yssel River and is folded into the underlying Tertiary beds, but the gray clay occupies only the provinces of Groningen, Drenthe, and Friesland, and nowhere extends west of the Yssel; it is not folded. As early as 1884 its limits were traced by Penck (22) through Gaasterland, Steenwijk, and Emblicheim to the Vecht. During the interglacial period between the accumulation of these two glacial clays, were formed, first peat beds and later, the Eem beds.

A similar succession was found by Van Calker (23) in Groningen, where a fossiliferous marine sand 15 meters thick, with peat and glacial scratched bowlders, occurred between two bowlder sand beds. Both Van Baren and Van Calker found the lower bowlder clay to contain Scandinavian erratics and the upper bowlder clay Baltic and even Finnish erratics.

In the province of Gelder, Lorié found the following succession in borings:

7. "Miniaturgrand," sand with occasional small bowlders.
6. Peat, indicating an elevation of about 20 meters above the present.
5. Marine clay.
4. Coarse shelly sand, termed by Harting "Eem system."
3. Bowlder clay, situated generally 29 to 38 meters below Amsterdam datum.
2. Rhine sands and gravels, 190 meters thick.
1. Pliocene.

From these sections and descriptions it is evident that the weathered bowlder clay below the Eem zone, representing the maximum

extent of the ice in Holland, is the equivalent of the lower glacial or first glaciation, of the north German plain; the gray clay overlying the Eem bed is thus the representative of the middle glacial, or second glaciation, while the ice of the upper glacial or third glaciation does not appear to have reached Holland.

F. Schucht (24) considers that the Lauenburg clay forms a good horizon for the correlation of the German and Dutch Quaternary. At various points in the Elbe valley and north toward Holstein the oldest glacial deposits are covered by sand, passing up into a thick, black clay, which he regards as a product of ice melting. Above this comes the Eem zone and the middle glacial. The Lauenburg clay can be traced into Friesland, where it occupies the same position between two bowlder clays. It helps to confirm the inferences drawn from the position of the Eem beds.

RELATIONS TO RHINE TERRACES.

The relations of these two bowlder clays to the Rhine terraces must now be worked out; they will be of considerable importance later in correlating the Fennoscandian and Alpine glaciations. The study of this question is not facilitated by the awkward nomenclature given to the Rhine terraces by the German geologists. The best classification appears to be the fourfold one adopted by Fliegel (25).

1. Oldest Quaternary gravels, forming the highest terraces (sometimes two or three) more than 100 meters above the present Rhine bed.
2. Chief terrace, sometimes termed "high terrace," especially by Dutch geologists, but higher than, and to be carefully distinguished from the "high terrace" as defined by Steinmann.
3. Middle terrace, including the terrace or terraces between the chief terrace and the low terrace. Steinmann's "high terrace" is included among these, as Fliegel considers it to have a purely local value. This inclusive term "middle terrace" seems most satisfactory, as being least likely to lead to confusion.
4. Low terrace, 8 to 30 meters above the Rhine bed.

In the Rhine gorge near Coblentz the oldest gravels lie at a higher level than the chief terrace, but farther north they descend to the same level and are overlain by them. In the same way the continuation of the high terrace is overlain by sands which upstream pass into the low terrace; the middle terrace, however, seems to die out.

The Rhine terraces between Bonn and the sea were studied in great detail by J. Lorié (26). We are only concerned here with those on the right bank, which he describes as follows:

The chief terrace is not the oldest, but above it, at Bonn, Pohlig discovered in 1883 an older gravel, lying at 210 to 215 meters above sea level; it is very much broken up, and can not be traced south of the Brohl Valley or north of the Ahr Valley. Near Brohl it lies at 260 to 270 meters.

The chief terrace on the right bank of the Rhine lies at irregular heights, but the normal highest points rise upstream as follows: Dingden, 54 meters; Wesel, 70 meters (or 54 meters above the Rhine); Bottrop, 81.5 meters (60 meters above); Duisburg, 95 meters (73 meters); Düsseldorf, 120 meters (90 meters); Keulen, 144 meters (106 meters); Bonn, 182 meters (136 meters above the Rhine).

The breadth of the high terrace varies from 3.5 to 15 kilometers; its western edge is always easy to follow as a clear slope, but rarely as a definite cliff, except near Düsseldorf.

The middle terrace lies with its upper surface at Sieg at 50 meters and at Obercassel, above Bonn, at 62 meters.

The low terrace lies at Dingden at 30 meters, at Sterkrade at 31 meters, at Duisburg at 33 meters, at Düsseldorf at 40 meters, and at Bonn at 52 meters.

As a result of his studies of borings Lorié found evidence of numerous changes of the channel of the stream, and of a considerable sinking of the floor.

The moraine of the maximum glaciation (lower diluvium of north Germany) crosses the Rhine Valley only between Crefeld and Nijmengen; here it underlies the gravels of the chief terrace (25, 20), but overlies and disturbs gravels of an old delta of the Rhine and Meuse (Van Baren, 1908). Farther north the gravels of the chief terrace are mixed with marine shells as well as with northern bowlders, indicating that at this point they are of fluvio-marine origin. From this it follows that the chief terrace falls in the Eem interglacial, between the lower and middle glacial of Germany, as well as at the conclusion of the preceding or lower glacial.

The equivalent of the middle glacial, the gray clay of the region east of the Yssel, rests on and disturbs the terrace on the east bank of this river corresponding to the chief terrace of the Rhine (20); similarly the middle glacial rests on and disturbs the chief terrace of the Rhine north of Crefeld, forming terminal moraines which indicate the limit of the ice (25).

When the chief terrace and the higher upper terraces are traced northward through Holland, they converge and descend below sea level, so that they lie in the same vertical sequence, and the chief terrace, being the younger, overlies the equivalent of the upper terraces. Between the two occur clayey beds and peat with a temperate fauna and flora, well known under the term "Tegelen stage," first described by E. Dubois (27) at Tegelen on the Meuse as an interglacial formation overlain by fluvio-glacial gravels corresponding to the chief terrace of the Rhine and underlain by still older fluvio-glacial gravels. In the following years various Dutch and German geologists found equivalents of the Tegelen stage at various

points in the Rhine Valley, and made their relations to the Rhine diluvium very clear; this identification of the clay bed in the Meuse and Rhine Valleys is quite legitimate because the underlying gravel is a joint delta deposit to the two rivers.

Fliegel and Stoller (25) found a plant-bearing clay with a similar flora to that of Tegelen at a series of points in the Rhine valley between Wylerberg near Cleve and Tonigsberg. At Wylerberg, under the gravel and sand of the chief terrace occur 11 meters of clay and fine sand, including a bed of brown coal 30 centimeters thick, below that again coarse diluvial gravel, not quite so coarse, however, as that of the chief terrace. This plant-bearing bed and its stratigraphical equivalents extend south and southeast into German territory far beyond Brüggen. A section at Hückelshoven near Erkelenz, on the edge of the Ruhr Valley, also showed a thick clay bed between the gravel of the chief terrace and an older gravel bed below.

Stoller gives the names of 35 plants from Wylerberg, all of which indicate a temperate and some a warm-temperate climate slightly warmer than the present in the same region. Their good state of preservation excludes the idea of transport from a distance. The flora has many elements in common with the flora of Tegelen, with which it appears to be contemporaneous. Fliegel and Stoller also studied the junction between the Tegelen stage and the chief terrace. The surface of the former has been modeled by flowing water except in the most northerly part, between Venloo and Tegelen, where the clay is covered by 3 meters of alternating sand and clayey sand; the sand is horizontally bedded and its upper 30 centimeters is very humous, indicating that for a considerable period its surface formed dry land.

Krause (28) also traced the oldest gravels northward, and found them to be overlain by the plant-bearing beds of Tegelen age. These oldest gravels here contain large erratic blocks, but Krause considers that these do not necessarily indicate ice transport. Farther upstream, at Coblentz, these oldest gravels have risen above those of the chief terrace, lying at 250 meters above sea level, while the latter never exceeds 240 meters, and are distinguished also by their much lighter color.

Lorié gives (29) the generalized result of some 40 borings on the west coast, as follows:

7. Dune sand.
6. Marine alluvium.
5. Exceptionally a bed of sand.
4. Eem zone.
3. Upper Rhine diluvium.
2. Fine sand.
1. Lower Rhine diluvium.

The tripartite arrangement of the Rhine diluvium, Nos. 1, 2, and 3, can be followed southward as they rise inland, the middle bed consisting of fine sand, loam, and peat beds. It is thus evidently the equivalent of the Tegelen stage, and the upper Rhine diluvium corresponds to the chief terrace, which is confirmed by its position immediately beneath the marine beds of the Eem zone. Its fluvio-glacial origin is shown even here by bowlders of granite and other rocks of northern origin, and also, according to P. Tesch (30) by the large quantities of feldspar crystals, orthoclase, and microcline which can only have resulted from the disintegration of granite rocks.

The fluvio-glacial origin of the lower Rhine diluvium, first maintained by Dubois, is more doubtful, for erratics of northern origin are extremely rare in it, though Lorié found pebbles of northern granite in a boring at Utrecht at 104 and 151 meters, and in a boring at Gorkum at 117 meters below sea level. Tesch concludes that the gravels are really fluvio-glacial, containing a considerable amount of northern material, but the ice edge lay some distance off, and the granite mostly became disintegrated into quartz and feldspar before coming to rest in the Rhine-Meuse delta.

SUMMARY.

The succession of events in Holland may now be outlined with considerable confidence as follows:

Preglacial.—In preglacial times the Rhine, like the rivers of north Germany, cut its bed below present sea level, indicating elevation above the present. At the beginning of the first glacial period the land began to sink.

First glacial period.—Lower gravel diluvium of Rhine, and gravels of Rhine-Meuse delta, with occasional bowlders rarely erratics of northern material, but a considerable amount of feldspar, probably northern. The ice must have lain some distance off to the northeast, but owing probably to a relative elevation of Scandinavia, the thaw-water channel ran across the mouth of the Rhine-Meuse delta.

First interglacial period.—A slight elevation, combined with a decrease in the amount of water brought down by the two rivers, allowed the formation of the plant-bearing clays of Tegelen, and their equivalents at Wylerberg and in the clays and peats of the middle division of the Rhine diluvium. Farther upstream the formation of the older gravel terraces ceased and the rivers eroded their valleys somewhat.

Second glacial.—The land ice reached the Rhine Valley, and formed the terminal moraines and ground moraine of the maximum glaciation of Holland. The land sank again slightly, and the gravels of the chief terrace and of the upper coarse Rhine diluvium were de-

posited. It was, however, still considerably above its present level, especially in the north, where the ground moraine is succeeded by peat deposits and not by clays with arctic Mollusca. After the climate had again become temperate, however, still further subsidence occurred, and the Eem clays were deposited, characterized by *Tapes aureus* var. *eemiensis*. The upper part of the chief terrace appears to have been deposited during this submergence, as marine shells are mixed with the gravels. In the Gelder this subsidence was followed by elevation, for the Eem beds are overlain by peat, and this again by a bowlder sand of glacial origin. (Lorié, 1906.)

After the formation of the chief terrace there followed a considerable period of elevation and denudation in the middle Rhine, during which the river deepened its bed at Bonn by more than 100 meters. In the lower Rhine the elevation, though less marked, was probably still noticeable, for there is a total absence of aqueous deposits between the Eem beds and a bed of sand equivalent to the lower terrace.

Third glacial.—The ice during this period failed to cross the Yssel River, and in the western part of the country the glaciation is represented only by occasional beds of sand. In the Yssel Valley the terminal moraines of this glaciation rest on and disturb the terrace corresponding to the chief terrace of the Rhine, and according to Van Baren, also rest on the equivalent of the middle terrace; we may therefore consider the middle terrace as contemporaneous with the first part of this glacial period, indicating subsidence at the beginning, but elevation at the end of the period.

No deposits are known in Holland belonging to the third interglacial. The land ice of the fourth glaciation did not reach Holland or the Rhine Valley, but by analogy with the chief and middle terraces, the lower terrace is attributed to this glaciation.

This succession does not by any means agree with the classification adopted by various Dutch and German geologists, so I will briefly discuss the latter.

Lorié, assuming that in north Germany the middle glaciation was the greatest, correlates with it the maximum glaciation of Holland and consequently also the Rhine chief terrace, thus making the middle and lower terraces both correspond to the last glaciation, and the lower Rhine diluvium to the lower glacial of Germany. The position of the Eem beds is sufficient to disprove this scheme.

P. G. Krause discovered at various points in the chief terrace clay and sand beds containing a small mammalian and molluscan fauna, which he regarded as interglacial and of the same age as the Tegelen flora, so that the chief terrace represents both the first and second glaciations of the Alps. Tesch, however, pointed out (31) that the

stratigraphical evidence is clearly against this conclusion, while the fauna is consistent with a considerably colder climate than the present. The fauna is probably late lower glacial.

In 1910 (32), however, Tesch had denied that the lower coarse Rhine diluvium corresponds to a glacial period, on the ground that no corresponding arctic fauna or flora is known. He considered that the chief terrace represents a single glacial period corresponding to the first of Germany and the first two of the Alps, there being a progressive increase in fluviatile activity and a continually increasing northern life element up to this point. In the paper in 1915 already referred to, however, he adopts a fluvio-glacial origin for this lower, coarse Rhine diluvium.

3. DENMARK.

Northeast of Holland lies Hanover and Schleswig-Holstein, the glacial deposits of which have already been described; to complete our survey of northwest Europe a brief reference to Denmark is necessary. Here, as in Holland, the Eem zone forms a safe base line for correlation. This was described by Madsen, Nordmann, and Hartz in their classic memoir of 1908 (33). In Denmark these marine temperate beds were found in borings to be overlain by two moraines; these were nowhere seen to be separated by later interglacial deposits, but their bowlder content is quite different, the lower bowlder clay containing erratics from the east Baltic and the upper erratics from southern Norway. The older moraine contains very much less crystalline and Cretaceous material and much more Paleozoic material than the younger. There is thus no doubt that the bowlder clay underlying the Eem beds, as in Holland, belongs to the first of the three glaciations of Germany.

Our knowledge of the second interglacial of Denmark is mainly derived from a very detailed study by Jessen, Milthers, Nordmann, Hartzog, and Hesselbo in 1910 (34) of a boring at Skaerumhede. This passed through 200 meters of Quaternary deposits before the chalk was reached. Two glacial series were found separated by a well-marked interglacial.

The older of these two glacial series was met with at a depth of 180 meters, or 157 meters below sea level, and was 20 meters thick, consisting of sands and gravels, and bowlder clay with many flints from the upper Danian, eruptive rocks from the eastern Baltic (Aland), and other southeast Swedish erratics (from Oesel and Oeland), showing that this bowlder clay was formed by an east Baltic ice sheet, evidently the same as that which formed the lowermost of the two moraines overlying the Eem beds in south Denmark. Both gravels and bowlder clay contain fragments of high arctic Mollusca probably derived from early glacial beds not yet known in situ.

Above these glacial beds comes the marine interglacial "Skaerumhede series," divided into three zones as follows:

3. *Yoldia* (*Portlandia*) *arctica* zone with purely arctic fauna and beds of gravel and sand with fragments of boreal Mollusca; 40 meters.
2. *Abra nitida* zone with a boreo-arctic fauna; 9 meters.
1. *Turritella terebra* zone with a purely boreal fauna; 74 meters.

The *Turritella terebra* zone consists of a mild, dark-gray clay marl, with black beds at the base and a rich marine fauna of pronounced boreal type. The most "temperate" species are found only in the middle of the zone; above and below are somewhat colder forms. The fauna indicates that the lower part of the zone was accumulated at a depth of 40 to 60 meters, the upper part at a depth of 60 to 80 meters.

Upward this zone passes gradually into the *Abra nitida* zone; black, very mild, stone-free clays with a pronounced boreo-arctic fauna accumulated at a depth of 20 to 40 meters. It is overlain with a sharp boundary, by the *Yoldia arctica* zone, a hard, gray, marine clay with isolated scratched bowlders and nests and layers of sand and gravels, with rolled shell fragments. The primary Mollusca of this zone, mostly broken, are high artic; the rolled fragments in the sand and gravel beds are secondary, and exclusively boreal, and must have been brought, like the nests of sand and gravel in which they lie, by ice from the deposits of the *Turritella terebra* zone. The lower part was formed in 20 meters, the upper part in 10 meters depth. In the upper 30 meters of the *Yoldia* clay are masses of moss and occasional seeds and leaves of higher plants, almost all indicating an arctic climate. (*Salix polaris*, *S. herbacea*, *Betula nana*, etc.)

The scratched erratics in the *Yoldia* clay come partly from the Christiania region (Rhomb porphyry) and partly from the Skagerrack; none are from the east Baltic, so that the ice must have had a purely northern origin. A comparison of the fauna of the *Yoldia arctica* zone with that of the older *Yoldia* clay of Vendsyssel shows that the two are identical and consequently of the same age.

The last glacial period in Denmark is represented by the bed of fluvio-glacial sand, gravel, and clay, 37 meters thick, at Skaerumhede, and the overlying sandy and stony moraine. Remains of this glaciation are found over a large part of Denmark, either at the surface or beneath later Quaternary deposits. So far, however, no interstadial deposits have been found in it comparable to those in the Baltic Hohenrücken of East and West Prussia, so that the Baltic oscillation as a readvance of the ice edge over Denmark apparently did not occur.

The postglacial deposits, however, show a well-marked climatic oscillation—the Allerod oscillation—which possibly corresponds to

this readvance. This was first described by Hartz and Milthers near Allerod in 1901 (35). The following section was seen in a brick kiln:

> Peat, 3 to 4 feet.
> Gray clay, free from stones, up to 6 feet.
> Bowlder sand.

In the gray clay, 6 feet above the bowlder sand, lies a bed of *Gyttja*, 1 foot thick, covered and underlain by clay. The flora of the clay, both above and below the *Gyttja*, is purely arctic—*Dryas octopetala*, *Betula nana*, *Salix polaris*, *S. reticulata*. The flora of the *Gyttja*, on the other hand, includes *Betula intermedia*, *B. verrucosa*, *Juniper communis*, etc., species not found in the clay and indicating less arctic conditions and consequently a retreat of the neighboring ice edge.

A similar succession has been found at various other localities, and Johansen (36) found the Allerod oscillation exhibited also in the fresh-water Mollusca, though his latest researches tend to minimize the subsequent fall of temperature (37).

The older *Yoldia* clay belongs to the conclusion of the last interglacial. Above this in North Jylland, and separated from it by a bed of bowlder clay, is another marine clay with *Yoldia arctica*, associated with a slightly different fauna, the upper *Yoldia* clay, 5 to 20 meters thick. Its base is formed by unfossiliferous sand and gravel, evidently a shore deposit, and it is similarly overlain by other sand and gravel beds. This clay therefore indicates a submergence. Its fauna includes two high arctic species, *Tellina Torelli* and *T. Loveni*, both of which occur living in north and east Greenland, Spitzbergen, and the Kara Sea.

The individuals of *Yoldia arctica*, however, are smaller, and the fauna differs slightly from that of the older *Yoldia* clay, indicating slightly more favorable conditions; Nordmann estimates the July air temperature as below 8° C. The bed evidently belongs to the melting period of the ice, so that both stratigraphically and climatically it falls on the same horizon as the older *Dryas* clay. It marks a period of subsidence, during which the submergence reached its maximum at Frederikshavn, where it amounted to about 50 meters, decreasing gradually to the south and southwest; its upper limit, however, is another shore deposit.

The upper shore sand and gravel is unfossiliferous, but as it represents an elevation it must correspond to the Allerod *Gyttja*, the air temperature during the formation of which is considered by Nordmann to lie between 12° and 15° C. More recent than this sand and gravel is the *Zirphaea* sand of Jylland, and Vendsyssel, characterized by *Zirphaea crispata* and other boreal and boreo-arctic species,

with a complete absence of high arctic species. It appears to correspond to the less arctic part of the upper *Dryas* period, with a mean temperature of 8° to 12° C.; it passes upward into the alluvial beds.

The sequence of events in Denmark may now be summarized as follows:

First glaciation.—Bowlder clay underlying Eem beds, with Baltic and Norwegian erratics. Land much higher than now at first, but subsided toward the close of the period.

First interglacial.—Represented by the Eem zone, during the formation of which the land lay somewhat below its present level.

Second glacial.—Bowlder clay with erratics from east Baltic and southeast Sweden. This again was marked by elevation, for the ground moraine of this glacial lies much below present sea level.

Second interglacial.—Skaerumhede marine series. At first the land lay about 100 meters above its present level; at the maximum of temperate conditions it had sunk to 40 or 50 meters, and at the conclusion of the interglacial to only about 10 meters above its present level. This period closes with the *Portlandia arctica* or older *Yoldia* period.

Third glacial.—Fluvio-glacial deposits and moraine with erratics from south Norway. Glacial conditions afterward gave place to an arctic vegetation, the *older Dryas period.*

By the conclusion of this glaciation the land had risen to slightly above its present level, for it is immediately followed by a shore sand and gravel, but this elevation at once gave place to subsidence, during which the younger *Yoldia* clay, with high arctic Mollusca, was formed.

Allerod oscillation.—A decided amelioration of temperature, with a July temperature of 12° to 15° C. As no marine deposits of this period are known, the land probably lay above its present level.

Younger Dryas period.—Recrudescence of arctic climate and arctic vegetation. To its close belong the *Zirphaea* sands, with a fauna somewhat less arctic than that of the younger Yoldia clay.

The exact chronological position of the younger *Yoldia* clay and the Allerod oscillation will be discussed in greater detail when the late glacial history of the Baltic is considered.

4. RUSSIA.

The standard region for a study of the glaciation of European Russia is the neighborhood of Moscow. In 1890 M. Krischtafowitsch (38) described in Schernigow Province two very dissimilar types of glacial deposits—bowlder clay below and fluvio-glacial sand and gravel above—between which he found at Troitskoe near Moscow lacustrine formations with *Quercus pedunculata*, *Alnus glutinosa*,

etc., with *Elephas primigenius*, etc. The plant remains indicate a milder and more temperate climate than the present in that region.

The greatest authority on the glacial period in central Russia is N. Bogoljubow, who makes out the following succession in the Government of Moscow (39). The remains of two glaciations are known, the older one represented by traces of moraines, and by bowlder sands and conglomerates, and the younger one by bowlder sand and more perfect moraines. The interglacial period between these two glaciations is divided by its deposits into three phases; first a "lake-wood phase," of lacustrine marl and loam, next a "steppe phase," of loess and loesslike sand loam, and finally a "wood phase."

The flora of the interglacial was investigated by W. Sukatchev (40), who finds indications that the climate was somewhat warmer than the present. There is thus evidence for at least two glaciations in central Russia, of which the first was the maximum. End moraines attributed to this glaciation have been found by P. Tutkowski (41) in Wolhynia, associated with Asar; this agrees with the limits of the first glaciation of eastern Germany, with which it is correlated by most Russian geologists. Near Ovrutsch (42) he found a mammal fauna in loess overlying bowlder sand, including *Elephas primigenius, Rh. tichorhinus, Ovibus fossilis;* this does not agree well with the Rixdorf horizon of Germany, but appears to be older. The succeeding glaciation, corresponding to the second in Germany, did not reach so far south as Wolhynia.

The center of distribution of these two ice sheets was in Finland, and Sir R. Murchison (43) found erratics of igneous rocks, chiefly granite, of Finnish types, 700 to 800 miles south of the parent rocks; this was confirmed by T. Belt (44) who also noted that in preglacial times the Russian rivers cut their beds much deeper than now.

In the east of European Russia the limit of glaciation turned north, along the Volga Valley and the Valley of the Petchora. In Finland two glaciations were recognized by R. Sieger as early as 1892 (45); the lower one of these is represented by ground moraine, the upper by a series of terminal moraines. Accompanying these are two distinct systems of striæ, the younger crossing and abrading the older as far as the terminal moraines, outside of which only the older system remains. The older striæ extend from the center of distribution in a uniformly radial direction, while the younger are affected by local irregularities of contour which the ice sheet producing the former was thick enough to override. In the southeast the limit of the younger moraines is Hango Head in the Gulf of Finland. The deposits in the lower course of the northern Dwina were investigated by Wollossowitsch (46). From two borings in Archangel he describes the following general section:

1. Present deposits and old alluvium.
2. Upper moraine.
3. a. Land and fresh-water sand deposits. b. Sands with plant remains.
4. a. Sand deposits with *Tellina balthica*, etc. b. Gray clay with *Tellina calcarea*. c. Clayey sandy sediment with *Cardium ciliatum*.
5. Loam with *Yoldia hyperborea*.
6. a. Gray fuller's earth with *Yoldia arctica*. b. Dark gray loam with *Pecten islandicus*, *Astarte*, *Leda*, *Balanus*.
7. Dark sandy clay with *Cardium edule*, *Mytilus edulis*, *Mya*, etc.
8. Lower red moraine.

From this the author makes the following generalizations:

1. In the region investigated two moraines are usually found, indicating two different glaciations.

2. The interglacial marine deposit is formed by two transgressions of salt basins—the oceanic transgression, which indicates an important subsidence of the continent, and that of the White Sea which was marked by the more important second subsidence. The subsidences alternated with corresponding elevations.

3. The postglacial oscillations of the sea level were considerably more important than the interglacial.

W. Ramsay (47) maintained that the fauna with *Yoldia arctica* was late glacial and not interglacial, but as we have seen in discussing the Skaerumhede series of Denmark, this species also occurs at the conclusion of the penultimate interglacial. The whole series, in fact, bears a considerable resemblance to the Skaerumheda series. If this interpretation is correct no equivalent to the first glaciation of Germany has yet been found in the Dwina region, either because investigations have not yet been carried to a sufficient depth or because the region during this glaciation was one of erosion and not of deposition. It is borne out by an observation of J. Geikie's, that between the limits of the old and middle glaciations lakes are few in number, within the limits of the latter they are more frequent, but are most abundant among the terminal moraines of the last glaciation.

There is one other deposit to which reference must be made—the bowlder-bearing formation of the south part of the Volga Basin, described by A. D. Archangelski (48) and A. P. Pavlov (49), in 1910. In the banks of the Volga is found a bed very closely resembling a moraine; elsewhere it is represented by bowlder sands. The bowlder sands lie on the highest part of the watershed; in their lower part the sands are coarse and contain layers and pockets of bowlders and erratics, among which chert with carboniferous fossils is noteworthy; the upper beds of the sand are finer and contain layers of sandy clay. Among the erratics crystalline stones are almost entirely absent. The cherts attain a diameter of one-half meter. Both authors consider the lower horizon as fluvio-glacial; the sands are older than the Caspian beds and apparently Pliocene; during their deposition the relief of the ground differed considerably from

the present and even the great river valleys did not yet exist. They were compared by Pavlov with the old bowlder beds of Germany and Switzerland, and, especially with the bowlder beds with a Pliocene fauna in southwest France, with the lower weathered moraine of the serra chain of Piedmont, and with the immigration of the polar fauna in the Mediterranean during the fourth upper Pliocene transgression, which corresponds to the first great European glaciation.

Professor Pavlov explains the lack of northern crystalline erratics partly by their slight durability in comparison with chert and partly by the mechanics of glacier work and nourishment; on the enormous stretch of the Russian plain there was heaped up, before movement began in a definite direction, a mass of snow, fern, and ice; in this erratics were frozen; nourishment and movement continued for a certain period, during which the bowlders from central Russia were carried into the Zaritzyn district, but the Finnish erratics only reached central Russia.

Although the existence of these bowlder beds with erratics is fairly established, there are difficulties in the way of giving them such a liberal interpretation. The existence of an isolated occurrence of ground moraine so far south, and entirely unconnected with any center of glaciation by similar deposits, does not seem probable. In Germany, as we have seen, the evidence for a Pliocene glaciation is of the scantiest, in spite of the immense detail of the researches in that country, and it seems certain that such a glaciation did not overstep the limits of the first of the well-known glaciations.

A more probable agent for the formation of beds in question seems to be river ice, which would easily deposit erratic bowlders of central Russian type in fluviatile sands. If we accept the late Pliocene age of the beds which is suggested by their position with regard to the drainage system, they may then represent, as suggested by M. Pavlov, a cold period corresponding to the first Alpine glaciation, though we have no proof that it was accompanied by the formation of an inland ice sheet in central Russia.

SUMMARY.

Late Pliocene.—Considerable elevation in all parts of European Russia.

Close of Pliocene.—Cold period. River ice on the Volga.

First glaciation.—Finnish ice attained its maximum extent, reaching far into the central Russian plain.

First interglacial.—(i) Lake-wood phase. (ii) Steppe phase. (iii) Wood phase.

Second glaciation.—Ice did not reach far into the central Russian plain, stopping short of Wolhynia.

Second interglacial.—Formation of Archangel series in lower course of northern Dwina. Finland free of ice. This interglacial was marked by a subsidence in Finland.

Third glaciation.—Reelevation of Finland. This glaciation was limited to a relatively small area in Finland and northwest Russia.

The limits of the second and third glaciations have not yet been traced in detail, and no formations similar to those of the Baltic interstadial have yet been discovered.

6. SCANDINAVIA AND THE BALTIC.

The centers of ice accumulation in Scandinavia were necessarily areas of erosion, where the thick ice swept the rock surface clear of all superficial detritus, and transported it often to very considerable distances. Consequently, every glaciation in these regions would tend to destroy the evidences of the preceding one, so that it becomes hard to tell whether there have been more than one glaciation, i. e., whether the ice retreats and interglacial periods of the peripheral regions extended into the center of ice distribution, leaving the whole country clear of ice, or only to its margin.

Nevertheless, there are a few traces of such deglaciation which, considering their necessary rarity, entitles us to assume the practically complete disappearance of the ice. These were discussed by A. G. Högbom in 1913 (50). He refuses to accept the thick sand beds, unfossiliferous or with only arctic remains, in Schonen as interglacial, since they show no evidence of any rank higher than interstadial. On the other hand, the fossiliferous deposits with a boreal fauna and flora overlain by glacial deposits described by H. Munthe (51) at Hernösand and Erikson (52) at Bollnäs, both in north Sweden, he considers to be very probably truly interglacial, as well as the fossiliferous beds intercalated in thick moraine deposits in Jaederen. As further evidence for at least one interglacial period he mentions the finding of teeth of mammoth in Schönen, Finland, and central Norway and remains of musk ox at Gothenburg.

The deposit at Hernösand appears to be the most important of these; it was described by H. Munthe in 1899, 1904, and 1909, and by A. G. Högbom in 1910. The section is as follows:

3. Typical feebly calcareous moraine clay; 3 to 5 meters.
2. Brown gyttja and sandy gyttja, rich in fossil Quaternary fresh-water and land organisms; 0.7 to 3 meters.
1. Glacial sand, gravel, and blocks (partly ice scratched); 2.8 meters.

The Gyttja is partly a somewhat impure diatom and *Cladocera* formation, partly more or less mixed with fine sand; it usually shows a breccia structure. The plants include *Betula odorata*, *B. nana*, *Pinus silvestris*, and *Picea excelsa*. It appears to have been de-

posited in a shallow fresh-water basin in a steep-sided valley at right angles to the direction of ice motion; the climatic conditions were arcto-alpine part of the time, but must have been somewhat better when *Betula odorata*, *Pinus silvestris*, and *Picea excelsa* grew. Its interglacial age is based not only on the stratigraphical evidence, which is very strong, but also on the similarity of its flora to that of undoubted interglacial deposits in Denmark and north Germany. *Picea excelsa* is a very characteristic interglacial fossil in Denmark. This Hernösand deposit lies exactly at present sea level.

J. Geikie (58) quotes a letter from M. Tornebohm describing a section in Wermland showing two bowlder clays superposed, the lower darker in color and containing fewer big stones than the upper. There is usually a sharp line of demarcation between them, and in some places the lower till has been partly broken up and denuded before the upper till was deposited, indicating an interval when the ground was free from ice.

A. G. Nathorst and H. Lundbohm have shown that earlier than the ice sheet which moved from north-northeast to south-southwest and formed the "lower diluvium" (middle glaciation) of north Germany, there must have existed another ice sheet which glaciated southern Sweden from east to west and accumulated a ground moraine with blocks from the east and southeast.

In southwest Norway, at Jaederen, south of Stavanger, K. Bjorlykke (54) found a *Cyprina* clay passing under and disturbed by bowlder clay and seen in borings to be underlain by other glacial deposits; he considers it to represent the cold part of an interglacial. Farther east, between Stavanger and the Christiania Fjord, A. M. Hansen (55) finds evidence of two main glacial periods, in addition to the later readvances; these he attributes to Geikie's Saxonian and Mecklenburgian.

Thus we see that there is considerable, though scattered, evidence that at least once during the course of the glacial period Scandinavia became practically ice free. At present it is not possible as a rule to allocate the interglacial deposits to definite horizons, but the *Cyprina* clay of Jaederen is considered by Bjorlykke to belong to the older interglacial, on both stratigraphical and paleontological grounds, and this would bring it into good agreement with the *Cyprina* clays of Denmark and north Germany. On the other hand, the flora of the Hernösand Gyttja is more in accordance with the upper interglacial of north Germany, and this is supported by the relative freshness of the deposits. We may accordingly suppose that there were at least three entirely distinct glaciations of Scandinavia, separated by intervals when the ice melted well back into the mountains, if it did not disappear altogether. During the earlier of the intervals the coast of Norway lay lower than at present; during the later both Norway and Sweden lay higher. From the

finding of littoral species of Mollusca at great sea depths off the west coast of Norway. Brögger concludes that at one period during the early Quaternary this region lay 2,600 meters higher than now. Further, on the coastal banks of west Norway littoral arctic Mollusca extend to depths of about 200 meters, indicating, in Brögger's opinion, that the land lay at nearly 200 meters above the sea even during the last glaciation.

The question of the occurrence of deposits of the Baltic interstadial in Scandinavia is quite different, and can be only approached by a careful comparative study of the history of the Baltic. The sequence in Denmark has been partly described already:

Third glacial period.—Fluvioglacial deposits and moraines with erratics from south Norway. Land slightly above present level.

Older Dryas period and *younger Yoldia period.*—Slight subsidence.

Allerod oscillation.—A decided amelioration of climate. Land above present level.

Younger Dryas period.—Return of cold climate.

Zirphaea sands.—Cold conditions; slight submergence.

After the deposition of the *Zirphaea* sands there is a gap, during which no deposits are known to have been formed, probably because of the considerable elevation of the land. This may correspond to the *Ancylus* period. It is followed by the older *Tapes* beds, representing the maximum subsidence in Denmark and also probably the temperature maximum.

Above the older *Tapes* beds are the younger *Tapes* or *Dosinia* beds, intermediate between the older *Tapes* time and the present both in level and climate. Lastly come the still forming beds with *Mya arenaria.*

The latter part of this sequence agrees very well with that in south Sweden, as described by numerous authors (56), but the earlier part is at variance. We may make the following comparison:

DENMARK.	SWEDEN.
Mya arenaria layers.	*Mya arenaria* layers.
Younger *Tapes* beds.	
Older *Tapes* beds.	*Litorina* beds.
(Climatic optimum.)	(Climatic optimum.)
(Gap.)	*Ancylus* lacustrine beds.
Zirphaea beds.	Deposits of *Yoldia* Sea.
Upper shore sand and younger *Dryas* period.	Great Scanian end moraine.
Allerod gytlja.	Baltic ice lake.
Younger *Yoldia* clay.	Ice over Schonen.
Lower shore sand.	Arctic plant beds of Schonen.
Older *Dryas* period.	Last glacial period.
Last glacial period.	

The correlation of the bracketed stages is uncertain, but the sequence of events was probably something like this: Denmark was ice free before Scania, so that the older *Dryas* period of Denmark may be unrepresented in Sweden, or it may be only slightly earlier than the arctic plant beds of Schonen (57), whose position is doubtful. The Baltic ice lake evidently corresponds to elevation in Denmark, which shut out the sea. As it was a period of rapid ice melting, and therefore relatively warm, it may correspond to the Allerod oscillation, in which case the fall of temperature and readvance or still stand of the ice marked by the Scanian end moraines must be correlated with the younger *Dryas* period, and the subsidence marked by the *Yoldia* Sea in the Baltic is marked in Denmark not by the younger *Yoldia* clay, but by the *Zirphaea* sands. This correlation is rendered more probable when we remember that the late glacial subsidence reached its maximum in Denmark, the more peripheral area, earlier than in Scania, the more central area. To represent the

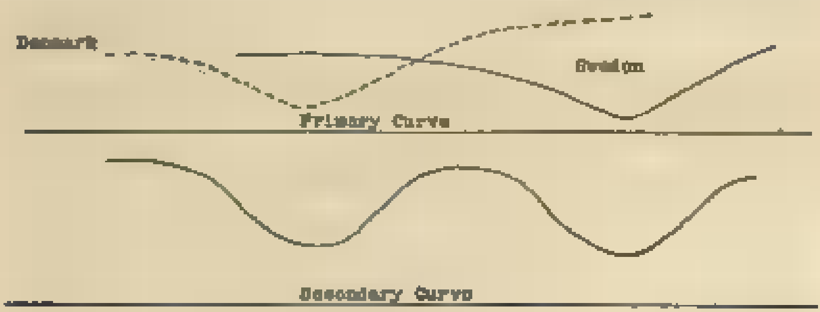

Fig. 1.

changes diagrammatically, we have to superpose two curves of changes of level—a primary, which in Denmark was always a phase earlier than Scania, and a secondary, which was the same in both districts (fig. 1).

Denmark.	Older *Dryas*.	Younger *Yoldia* period.	Allerod oscillation.	Younger *Dryas*.	*Zirphaea* beds.	Gap.
Scania.	Ice. Schonen beds.	Ice covered.	Ice retreat.	Scanian end moraine.	*Yoldia* clay.	*Ancylus* beds.

In Scandinavian late glacial, the depression of the *Yoldia* Sea and its equivalents and the succeeding elevation appear to have progressed inward to a central zone over the east of Sweden; here, where the ice was thickest and most permanent, the consequent depression was the greatest, reaching more than 250 meters, and the land took the longest time to recover from the effects of the load.

We have next to compare the sequence in Denmark and Sweden with that worked out by C. Brögger in the Christiania region, 200 miles farther north (58). This sequence and the variations of level of the land are as follows:

The older *Yoldia* clay is a reconstructed bowlder clay with 25 species of high arctic Mollusca formed immediately behind the retiring glacier, indicating a land level about 30 meters lower than the present. The land then sank another 45 meters, while the climate ameliorated, so that one finds the larger form of the high arctic *Portlandia arctica* Gray of the older *Yoldia* clay represented by smaller forms of the same mussel in the younger *Yoldia* clay. At this time the climate was similar to that of the west coast of Spitzbergen. Immediately above the younger *Yoldia* clay is a clay deposit with a more arctic deep-water fauna, chiefly *Arca glacialis* Gray represented by a large form. This older *Arca* clay represents a submergence of about 100 meters and is only found outside the great Ra moraine or in immediate connection with it, whereas the following middle *Arca* clay, with a smaller form of *Arca glacialis*, representing a slight amelioration of climate and a still greater submergence, occurs also inside the Ra moraine. The latter, therefore, which represents a prolonged still stand of the ice with possibly a slight readvance, evidently corresponds to the older *Arca* clay.

The continuation of the late glacial sequence in the Christiania region is described by Brögger as follows:

The middle *Arca* clay, indicating a submergence up to 150 meters, is followed in continuous series by the younger *Arca* clay with a still smaller form of *Arca glacialis* and many boreo-arctic Mollusca. The occurrence of this fauna in connection with a corresponding shore fauna, which occurs in the *Portlandia* clay with *Portlandia lenticulata* and in connection with the series of moraines in the Christiania Valley, indicates in this region a submergence of the land to about 200 meters. The progressive sinking still continued, as shown by the marine shores of the neighborhood of Christiania, where terraces of accumulation with a boreo-arctic fauna and corresponding erosion phenomena indicate the shore at a height of 216 meters above sea level. Corresponding to this sinking of the land there occurs at many places on the present shore line a fossil *Lophelia* fauna, and this period coincided with the epiglacial period, during which the great moraines were covered by the southern end of great inland lakes. After this the land began to rise and the climate ameliorated steadily. The upper, middle, and lower *Mya* banks, at 200 to 100 meters, corresponding to the older *Cardium* clay, are followed by the younger *Cardium* clay, 100 to 80 meters, the

upper *Ostrea* banks, 80 to 66 meters, the upper *Tapes* banks, early neolithic in age, at 60 to 30 meters, the lower *Tapes* banks. *Scrobicularia* clay, and *Mya* banks, the latter only just above the level of the sea. There is no trace of either the *Ancylus* elevation or the *Litorina* subsidence, but the horizon of the latter is marked faunally and climatically by the *Tapes* banks.

The only part of Norway where any trace of the *Litorina* subsidence has been found is in Christiansand, the southernmost province, where D. Danielsen (59) found that after a maximum late glacial subsidence of 30 meters the land rose to about its present level, and then sank again somewhat. J. Holmboe (60) also records that during a wreck off the south coast of Norway in 1909 peat fragments were torn from the sea floor, consisting of parts of two beds, one arctic, with *Betula nana*, and the other representing a climate somewhat warmer than the present, and evidently belonging to the *Ancylus* period. During the formation of both these beds the land must have lain at least [illegible] meters higher than at present.

Owing to the dissimilar changes of level, correlation with Scania can best be effected climatically.

	Scania.	Christiania.	Denmark.
Postglacial optimum.	*Litorina* beds.	*Tapes* banks.	Older *Tapes* beds.
Postglacial elevation.	*Ancylus* beds.	Submerged peat of Christiansand.	(Gap.)
Beginning of amelioration.	*Yoldia* beds and recession.	*Arca* clays, moraines.	*Zirphaea* beds.
Great end moraine.	Great Scanian moraine.	Ra-moraine.	Younger *Dryas* period.
Interstadial.	Rapid ice recession.	Younger *Yoldia* clay.	Allerød oscillation.
Glacial period.	Ice covered.	Older *Yoldia* clay, ice covered.	Younger *Yoldia* beds. Older *Dryas* period, ice-covered.

This correlation is to some extent supported by the fact that it makes the maximum subsidence in Norway nearly coincide with that in Scania. If it is correct, it indicates that Baltic interstadial deposits are unknown in either Norway, Sweden, or Denmark, save possibly the arctic fresh-water beds of Schonen, but are replaced instead by deposits of later interstadia. Archeologically also the correlation is supported, for the stone age occurred during the *Ancylus* and *Litorina* periods in Sweden, and during the climatic optimum in Denmark and Norway, while the succeeding period of elevation in the Baltic coincides with the bronze age.

Direct comparison with the north German coast is impossible, because this more peripheral region was elevated above present sea level at the close of the last glacial period, and was not subsequently

submerged, except possibly for a small area in the northwest, where *Litorina* deposits occur below sea level (61). No cold period subsequent to the ice melting has yet been proved in the peat bogs, so that the Scanian end moraine at least is unrepresented.

Nordmann (62) applies the term "older *Yoldia* clay" to the two beds with *Yoldia* (*Portlandia*) *arctica*, and the term "younger *Yoldia* clay" to the bed with *Portlandia lenticulata*, and considers that the latter, with the associated epiglacial moraines, represents the *Zirphaea* sands of Denmark, while the *Arca* clays represent the Allerod oscillation. This, however, is not borne out by the climatic values of the various species of Mollusca, and it further leaves the great Ra-moraine quite unaccounted for. The epiglacial moraine appears to represent a later cold period of considerably less intensity.

In the Bergen region the conditions were described by C. F. Kolderup (63) as follows. The highest well-marked shore line lies in the west at 50 to 60 meters and in the east (inner fjords) at 60 to 70 meters. These terraces contain *Yoldia arctica*, and are termed by Kolderup the "Yoldia" or "epiglacial terraces." They do not mark absolutely the highest level of the sea, for here and there a small terrace is found a few meters above, but indicating only a very short stay at this level. As the inland ice melted, the ice divided into local glaciers, whose ends reached the sea. A still stand or slight readvance at this stage is marked by a few important end moraines, which correspond to the Ra-moraines of the Christiania region. Arctic mollusca, indicating a climate colder than that of the extreme north of Norway, occur in beds mixed up with these moraines, but the *Yoldia* terraces, with a fauna like the present one of the White Sea, belong to the end of the Ra-moraine period. Conditions were thus essentially similar to those of the Christiania region.

At Christiansand and Trondhjem, J. Rekstad found that glacial conditions continued until the maximum subsidence (76 to 134 meters) was reached, after which it ameliorated, and present conditions (*Tapes* period) obtained when two-thirds of the ensuing elevation had taken place.

Still farther north conditions have been studied by O. T. Grønlie (64) in the neighborhood of Tromsö, about latitude 69 north. He found that during the late glacial subsidence the climate continued arctic, but when elevation commenced conditions became milder, ultimately milder than the present. Renewed subsidence in the "*Tapes* period" was associated with a deterioration of climate, but at the new minimum land level the climate again became milder. This subsidence was probably the equivalent of the *Litorina* subsidence, which, as will appear later, was very widespread over the northernmost part of the North Atlantic and the Arctic Oceans.

6. GREAT BRITAIN.

In applying to the glacial deposits of Britain, the classification worked out for north Europe, we find that even in eastern England, where deposits of two glaciations occur associated, a direct proof of a difference in age is more difficult. But the bowlder clays which on stratigraphical and paleontological grounds are classified as belonging to the first glaciation of England are vastly more weathered and eroded than those of less extent which are classified as belonging to the second glaciation. Moreover, almost without exception every locality in England where older paleolithic implements have been found lies outside the limits of this younger bowlder clay. These implements are associated with the well-known warm-temperate fauna of Chelles, which is incompatible with a climate appreciably colder than the present; they are indisputably younger than the older bowlder clay and older than the younger bowlder clay, and on these grounds alone we should be justified in inferring two glacial periods in England separated by a temperate interglacial period.

The starting point must be S. V. Wood's division of the East Anglian drifts into contorted drift, middle sands and gravels, and chalky bowlder clay. The lower tills of Cromer and the arctic fresh-water bed can not be separated from the contorted drift. At Cromer the middle sands contain *Nassa reticosa*, *Anomia*, *Dentalium*, and *Scalaria Groenlandica* (65). The same bed at Yarmouth contains a much larger fauna of mollusks and ostracods, but still boreal and arctic (66). They form no evidence for an interglacial period.

Northwest of Cromer isolated hills rising above the Fens show marine sands and gravels; these contain a northern but not arctic molluscan fauna with in places *Corbicula fluminalis*, as at March. They are associated with old valley gravels, containing Pleistocene mammalia (*Hippopotamus*, *Elephas antiquus*, *E. primigenius*, *Rhinoceros tichorhinus*, and *Felis spelaea*); this resembles the fauna of the older interglacial of north Germany. The beds also contain flint implements, Chellean or Acheulian type; they rest on chalky bowlder clay.

The next clear sequence is that of the coast of Holderness (68), where again there are four bowlder clays, the upper two separated by stratified gravels. The uppermost division is the Hessle bowlder clay, quite indistinguishable lithologically from the lower clays, but with smaller bowlders and no shell fragments. S. V. Wood's section was at Hessle, where it overlies the mammaliferous gravel, but overlaps it on to the chalk. The relations of the Hessle clay can be seen more satisfactorily at Kelsey Hill, in Lincolnshire, where bowlder clay 13 feet thick, but very much weathered, overlies the marine gravel, which here, opposite the Humber gap, contains great

numbers of shells of *Corbicula fluminalis*. Beneath the gravel, borings show another bowlder clay. At Grimsby, also, two bowlder clays are separated in places by gravelly sand. This marine bed is in fact found at a great number of localities; it was considered by Wood and Rome (69) as a distinct deposit, termed by them Hessle sand, between the purple clay and the Hessle clay, and C. Reid states that there is no doubt whatever about its position between two bowlder clays. It can be traced around the greater part of the old bay of Holderness, and, where the ancient chalk cliff is low, extends for some distance inland. The land sank gradually to a depth of about 100 feet, and rose again gradually, so that except in parts of Lincolnshire there is an almost complete absence of a cliff bounding the gravels at this level. There is a distinct line of erosion at the bottom of the gravels and another at the top. The only still-water deposits of this horizon are those at Croxton and Kirmington.

The marine fauna is by no means poor. Sixty-one species are known, slightly northern, but not arctic. Except *Corbicula fluminalis*, there are no exclusively southern forms; 12 do not now range so far south. The great majority are living British forms, many of which do not extend far north. The fauna agrees almost perfectly with that of March in the fen land. The mammalia include *Elephas primigenius*, *Cervus tarandus*, *Bison priscus*, and *Rhinoceros leptorhinus*. We may safely assign the marine gravels to a period of milder climate than the bowlder clays preceding and following it. The flora from the estuarine peat at Kirmington (70) supports these conclusions.

After the melting of the ice of the last glaciation the land lay about 40 feet lower than at present; the beaches of this submergence have all been destroyed by the encroachment of the sea, except a raised estuarine beach extending for some miles near Barton, but river gravels in the chalk valleys and the positions of some of the peat deposits, e. g., on Kelsey Hill, indicate a saturation level about 40 feet higher than now. Most of these deposits contain a temperate flora of oak and hazel, with *Cervus megaceros*, *Bos primigenius*, and *Elephas primigenius*, but at Holmpton temperate lacustrine deposits belonging to this stage are overlain by a laminated peaty bed with *Betula nana*, which is so characteristic a northern form that it seems sufficient evidence of a return of a colder climate; this arctic bed agrees with similar postglacial arctic beds in the Pennine district to be described.

Just north of Holderness the glacial succession has been studied by G. W. Lamplugh in the Flamborough Head district (71). The equivalents of the four bowlder clays found by C. Reid in Holderness are recognized, but at a higher level. The purple bowlder clay is separated from the equivalent of the Hessle clay by unfossiliferous

gravels, but Lamplugh does not consider them as interglacial. He regards the Holderness gravels as possibly marine, but contemporaneous with the continuous formation of bowlder clay in other parts of the area, during an oscillation of the ice edge; this suggestion was considered by C. Reid to be negatived by the fauna.

In Durham C. T. Trechmann (72) found a somewhat similar sequence—lower shelly bowlder clay with Scandinavian bowlders, overlain in places (especially in cavities in magnesian limestone) by current bedded shelly sands, probably marine, and this in turn by Cheviot bowlder clay with Scottish and Cumberland erratics, probably equivalent to the Hessle clay. In Northumberland Doctor Woolacott (73) found only one bowlder clay, but underlying it north of the Wansbeck he found a coarse gravel which may represent the gravel beds of the Durham coast.

Near Hartlepool the Cheviot clay is overlain by a gravelly bed extending fairly continuously at an altitude of 60 feet; Doctor Woolacott regards this as the continuation of a raised beach which he discovered resting on the bowlder clay from Seaham to Castle-Eden-Dene. The beach decreases in height both north and south from 150 feet at Cleadon and Fulwell to 50 feet at Seaham and 60 feet at Castle-Eden-Dene, while a raised beach at Saltburn lies at 30 feet.

Returning to East Anglia we find that the contorted drift breaks up into isolated mounds and ridges as it passes southward, but the marine sands of Cromer and Yarmouth merge into S. V. Wood's widespread "middle glacial" and the chalky bowlder clay forms a widespread sheet. No traces of temperate deposits have been found in the "middle glacial." It seems that the great subsidence in Holland during the early Quaternary was sufficient to deflect the Scandinavian ice from East Anglia farther eastward. In this way would be explained the total absence of a bowlder clay underlying the chalky bowlder clay in central England, a fact otherwise incomprehensible. And, further, the deep river valleys of Norfolk and Suffolk, which extend below sea level, and are post North Sea drift, but pre chalky bowlder clay, are possibly subglacial fjords (74).

The archeological horizon of the chalky bowlder clay is fixed as pre-Acheulian by the well-known section at Hoxne (75) which gives the section—

4. Loam and gravel with Acheulian implements and widespread fauna and flora.
3. Black loam with numerous arctic plants; 13 feet.
2. Lignite and lacustrine clay with temperate plants and mollusca; no arctic plants.
1. Chalky bowlder clay and glacial sand.

From this section it appears that not only is the chalky bowlder clay older than the Acheulian culture, but is separated from it by a

long period of temperate climate and another long period of arctic climate.

Returning now to Cromer, we find underlying the arctic and glacial sequence there the Cromer forest bed, which contains a temperate fauna including an admixture of Pliocene forms—including *Machaerodus*, *Rhinoceros etruscus*, and *Elephas meridionalis*—with Pleistocene forms, including *Elephas antiquus* and a rare form described as *E. primigenius*, but which according to H. Pohlig (76) really belongs to his species *E. trogontherii*. This agrees closely with the St. Prestian of France.

The associated flora has been shown by C. Reid and Dubois (77) to be almost identical with that of the Tegelen clays already described (see p. 290) as underlying the chief terrace of the Rhine, the terrace which we have already seen to be contemporaneous with the first glaciation of north Germany. The glacial deposits of eastern England may accordingly be correlated as follows:

EASTERN ENGLAND.	NORTH EUROPE.
Cromer forest bed.	Clays of Tegelen.
Arctic fresh-water bed.	First glaciation of north Germany and Holland.
North Sea drift and Scandinavian drift of Durham.	Chief terrace.
Arctic marine sands of Cromer and Yarmouth.	
Chalky boulder clay and Scottish clay of Durham.	
Marine sands and gravels of March and Holderness.	Older interglacial of north Germany with *Corbicula fluminalis*.
Temperate lacustrine beds of Hoxne.	*Cyprina* marine beds of Denmark and Holland.
Cheviot boulder clay of Durham.	Middle terrace of Rhine.
Hessle boulder clay.	Second glaciation of north Germany.
Arctic beds of Hoxne.	
Brick earths of Hoxne (Acheulian).	Second interglacial of North Germany.
Temperate peat of Holderness.	
Arctic peat of Holmpton.	Baltic glaciation of north Germany.

THAMES VALLEY.

According to Messrs. Hinton and Kennard (78), the history of the lower Thames can be divided into the following stages:

1. Plateau gravels formed.
2. Hill gravels formed; Chellean implements in places.
3. Highest terrace of Thames (130 feet at Dartford Heath) *Corbicula fluminalis*.
4. Elevation of 30 feet and formation of 100-foot terrace. Galley Hill man. *Elephas*, *Leo*, *Hippopotamus*. Fauna at Swanscombe includes *Microtus intermedius*, Reindeer, *Elephas antiquus*; Acheulian. Mr. Leach, as a result of investigations of a Dartford Heath, suggested

that the 130-foot and 100-foot terraces are not really separate, but Mr. Monckton found four well-marked terraces in the valley of the Wey at Farnham, evidently corresponding to those of the Thames.

5. Elevation of about 50 feet. A very long period of time elapsed after the Thames reached its new base line, for the lateral erosion was enormous. The extensive gravels of the middle terrace were deposited, with brick earths to the east. These brick earths must have been laid down in still or slow-moving water, and the authors suggest that the Thames was at this period ponded back owing to differential elevation to the north, reaching a maximum over the great flat plain of the North Sea. The contemporaneous fauna includes *Elephas primigenius*, *E. antiquus*, *Rhinoceros megarhinus*, *R. leptorhinus*, *R. antiquitatis*, *Ovibos moschatus* and *Spermophilus erythrogenoides*. Mousterian.
6. Elevation of about 20 feet. A fourth terrace of gravel ("third terrace") deposited. Resting on this terrace at Uxbridge are Magdalenian implements.
7. Great elevation (at least 60 feet) and formation of buried channel.
8. Gradual sinking to present level.

For many reasons the 130-foot and lower terraces must be more recent than the maximum glaciation (chalky bowlder clay). Probably, as suggested by Mr. Salter and by Messrs. Sherlock and Noble (70), prior to this the Thames occupied a more northerly course, but was forced into its present position by the ice.

That the climate was still cold when the 100-foot terrace began to be formed is shown by the animal remains, which include reindeer and *Microtus*, but it was ameliorating rapidly, and finally permitted the presence of *Hippopotamus*. The occurrence of *Corbicula fluminalis* in the gravels of the highest terraces allies them with the marine gravels of March and Holderness, already described. According to H. Menzel this mollusk is characteristic of the first interglacial of the whole of northern Europe (i. e., after the first glaciation of north Germany). The presence of *Paludina diluviana* is also characteristic of the first interglacial of northern Europe.

The fauna of the middle terrace, deposited after considerable elevation is very peculiar, containing a mixture of warm and cold forms—the presence of *Ovibos moschatus* and *Spermophilus* indicate a much colder climate than *Hippopotamus* could exist in, and there are also a number of deposits on this horizon which indicate very severe climatic conditions. At Grays and Crayford the brick earths cover paleolithic floors with Mousterian implements. A similar floor at Stoke Newington is overlain by the "warp and trail" of W. G. Smith, generally considered as evidence of a severe climate.

On the same level as the third terrace, but in the Lea Valley, and also both overlain and underlain by brick earth, are the arctic glacial beds of Ponders End, described by S. W. Warren and others in 1912 (80).

The phanerogam flora indicates conditions only found to-day within the Arctic Circle, but less rigorous than those at Spitzbergen.

The sequence of stages in the Thames Valley may accordingly be made out as follows:

1. Maximum glaciation of eastern England—Chalky bowlder clay of Finchley.
2. Highest and 100-foot terraces of Thames with *Corbicula fluminalis* and *Paludina diluviana*. Chellean and Acheulian correspond to the marine gravels of March and Holderness.
3. Period of erosion.
4. Middle terrace, temperate at first, but becoming cold later. Acheulian Mousterian.
5. Cold period. Arctic beds of Lea Valley; "warp and trail."
6. Erosion, late Mousterian period; no evidence as to climate.
7. Low terrace formed. Probably cold. Solutrean to Magdalenian.

The correlation of the Quaternary stages of eastern England and the Thames Valley with those of Holland and north Germany is very clear, if ordinary stratigraphical and paleontological methods are employed. The Cromer forest bed and the Tegelen plant beds must be equivalents on the grounds of both stratigraphy and flora. Each was immediately followed by the maximum glaciation of the district. The close of the glaciation was marked in each case by a submergence, characterized in the north by marine formations (Holderness gravels, Eem beds) and in the south by river terraces (100-foot terrace, chief terrace). The characteristic Mollusca of these beds on both sides of the North Sea are, first, *Corbicula fluminalis*; second, *Paludina diluviana*. Finally, we have in both east England and Holland a minor glaciation, associated with the Mousterian industry, and with the middle terrace group of the rivers.

SOUTH COAST.

South of the Thames Valley no bowlder clay is known, but there are other evidences of a severe climate in the coombe rock or "head" and in the presence of large erratic bowlders.

The section at Brighton was described by Mantell in 1833 (81):

a. Elephant bed (coombe rock).
b. Ancient shingle (with erratics).
c. Ancient sand.
d. Base of cliffs, of chalk rock.

According to Mantell, the junction of the coombe rock with the shingle was marked by a layer of shells, including *Cardium edule*, *Mytilus edulis*, *Litorina litorea*, and *Purpura lapillus*, but in 1914 this was not visible; instead the junction was marked by a layer of chalk pebbles. A few hours' search in the shingle beds yielded a large number of erratics, many of them gray and pink granites of north-

eastern types. In the coombe rock implements of Acheulian-Mousterian type have been found near Brighton. West of Brighton there is a section at Portslade showing typical "head" underlain by sand and clay with *Mytilus*, *Litorina*, and pebbles, some igneous.

At the bottom of the sand was found a piece of hard purple quartzite, 4 inches long, quite angular, and broken into two pieces in situ. The marine beds here are about 10 feet lower than east of Brighton, either because they were formed farther seaward or because the submergence at this period diminished westward.

At the base, resting on and squeezed into Bracklesham clays, are the Selsey erratics, overlain by marine and estuarine beds with temperate (southern) Mollusca and redeposited erratics. The Mollusca include *Corbicula fluminalis* and *Bithynia tentaculata*. These beds are overlain by the raised beach, resembling that of Brighton, but at a lower level, and this again by "head," here a loam.

Further west the raised beach and head are well seen at Selsey Bill and near Chichester, but the phenomena here are more complicated. They have been described by C. Reid in several papers (82). Reid correlates these temperate deposits with *Corbicula fluminalis* with the Thames gravels with the same shell, the Clacton raised beach, with *C. fluminalis* and *Paludina diluviana*, and the gravels of March and Holderness. He remarks:

> Though the land and fresh-water species show little change of climate between south and east, there exists a marked difference in the marine Mollusca. In Sussex the marine fossils seem to indicate a sea warmer than the air, while in the eastern counties the air was apparently warmer than the sea.

The Selsey Peninsula is backed by a line of old cliffs which cut obliquely across the chalk and Eocene, and associated with this in places are remains of the corresponding marine sands and gravels, at a level of about 100 to 105 feet at Tortington Common, 120 feet near Arundel, 90 feet near Boxgrove, 130 feet at Waterbeach, where it contains large blocks of *Pholas*-bored and worm-eaten chalk, and occasional small shells. Here it is overlain by coombe rock, chalky paste with angular flints, which passes southward into loam.

North of the Chalk Downs no trace of these marine deposits has been found, so that the submergence must be older than the erosion of the valleys. Further, as the marine sands and shingle can not be related to the much lower beach shingle at Selsey and Brighton, they must correspond to an earlier submergence of 100 feet, which may be related to the submergence of 100 feet (130-foot terrace) in the Thames Valley, immediately succeeding the first glaciation.

The large bowlders of the Selsey foreshore must have been ice-carried, and evidently indicate a considerable submergence, for the ice which floated a 2-ton bowlder must have been thick, so that it is probably not far different in age from the raised beach of Chichester.

Farther west occurs the raised beach of Portsdown Hill, near Portsmouth, at nearly 100 feet above sea level, described by Prestwich (83). From here he traced the beaches along the south coast into Devon, Cornwall, and South Wales, finding them at the following levels:

Between Blackgang and Freshwater, 80 feet.
Portland Bill, 24 feet to 50 feet, rising northward.
Torbay, 30 feet.
Plymouth, 35 feet.
Land's End, about 20 feet.
Newquay, 10 to 25 feet.
Weston Super Mare, 25 feet.
South Wales, 12 to 20 feet.

The beach at Portland Bill consists on the western side of unfossiliferous shingle, on the east, where it was more sheltered, of shelly sand giving the following section:

4. Angular rock débris ("head"), 5 feet.
3. Loam with land shells and layers of angular débris, 6 feet.
2. Sand, 1½ feet.
1. Raised beach, 3½ feet.

The shells in the sand are often very abundant, of the usual north British type of this raised beach.

In south Devon and Cornwall the beach is overlain by sands with marine fossils—limpet, mussel, crab—this in turn being overlain by "head." In north Devon, according to H. Dewey (84) the succession is:

Bed of rounded stones (?).
"Head."
Cemented sand with warm temperate fauna (*Helix virgata*, *H. cantiana*, *Bulimus contrireosus*).
Raised beach with bowlders, probably from west Scotland.

In Glamorgan (East Gower) the relations of the raised beach with undoubted bowlder clay were made clear by Mr. Tiddeman (85), the general succession being—

5. Recent head.
4. Gravelly bowlder clay.
3. Ancient head.
2. Blown sand, often cemented into sand rock.
1. Raised beach, with erratics.

This bowlder clay contains materials of northern and northeastern origin, and is shown by the striæ associated with it to have come from those directions. But there occur, scattered over the hills, large erratics which can only have come from the west, or from the shores of the Irish Sea. These include many from St. David's

Head, volcanic ash probably from Skomer Island, and also chalk flints. These presumably come from another bowlder clay of western and northwestern origin, which has been destroyed in most places. The only section in Glamorganshire where it has undoubtedly been found in situ is at Pencoed. Here a gravelly drift packed with rounded bowlders of Pennant grit, many striated, with lenticular bands of gray sand or fine gravel containing coal dust, is separated by a sharp undulating junction from an underlying red clay containing contorted bands of fine sand, and including, besides local rock, western erratics and chalk flints. A similar red clay occurs in the Ewenny Valley, overlain by gravel, which may be either a river gravel or the southern extension of the gravelly drift. Its western erratics and red color, taken in conjunction with its discontinuous nature, show that it is older than the gravelly clay overlying the raised beach. The relations of these older glacial remains to the raised beach have not yet been conclusively determined. Pebbles closely resembling chalk flints have occasionally been found in the raised beach of Gower; it is possible that they may really be Carboniferous or Liassic cherts, but if they are flints they are strong evidence that the glacial remains are older than or contemporary with the beach.

In the Gower Peninsula we also have the raised beach associated with cave deposits containing a temperate fauna of Chelles type. The general section as described by the late H. Falconer (86) is:

5. Dark colored cave earth with ancient British pottery.
4. Stalagmite with limestone breccia (*Ursus*, *Bos*).
3. Ocherous cave loam and dark sand (*Elephas antiquus*, *Rhinoceros leptorhinus*, *Rh. antiquitatis*, *Hyaena*, Wolf, *Ursus*, *Bos*, *Cervus*, *Meles taxus* and *Putorius*).
2. Stalagmite.
1. Yellow sand abounding with shells of *Litorina rudis* and *L. litoralis*, and at the top *Clausilia nigricans*.

In Minchin Hole the mammalian remains were found actually in the marine sand, and if we accept Falconer's conclusion that the marine sands and the breccia of the caves correspond with the raised beach and the lower "head," the mammalian remains must be earlier than the gravelly bowlder clay.

At Milford Haven the raised beach overlain by "head" is only 6 feet above high-water mark and farther north it gradually descends to sea level.

The interglacial age of the fauna of the Gower Caves is further borne out by the sequence of deposits in the caves of Pont Newydd, near St. Asaph in North Wales (87) where a fauna almost identical with that of Gower was associated with a human tooth and with rude, hatchet-shaped implements of quartzite, made from peb-

bles which must have been obtained from the neighboring glacial drift. The section is:

4. Clay with angular and subangular fragments and pebbles of limestone and pebbles of Denbighshire sandstone and grit, felstone, etc., and bones of the usual cave mammalia.
3. Stalagmitic crust up to 2 feet in thickness.
2. Loam containing pebbles and the bones and implements described above, all more or less cemented.
1. Coarse shelly sand.

Near the mouth, No. 4 appears to pass horizontally into a continuation of the upper bowlder clay of Lancashire, Cheshire, and Flintshire. W. Boyd Dawkins considers it to be derived from the wash of this clay.

From these details certain generalizations can be made about the raised beaches. The first is that at Selsey and Chichester there are evidently two raised beaches, series of different ages, the older one represented by the marine sands of Chichester, the large erratics, and the clay with a Pleistocene marine fauna, though the latter, being now about sea level, represents only a slight elevation. The younger, the raised beach of Selsey, passes up into the "head," and must be of very nearly the same age; this characteristic directly connects it with the raised beach of Brighton.

Farther west and northwest the raised beaches descend gradually in height to sea level, and there is never any sign of a duplication. They never pass up into "head," and are occasionally overlain as at Selsey, Portland, and in North Devon by marine or eolian sands with a temperate fauna. In the Gower Caves the raised beach passes up into deposits with a temperate mammalian fauna.

Marine shells have been found in the beach itself at various localities; the aspect of the fauna as a whole is rather northern than southern, but without any peculiarly arctic types. All the species inhabit the British coasts between Shetland and Yorkshire, and Jeffreys regarded the fauna as similar to that of existing Shetland beaches.

On the other hand, the beaches often contain ice-borne bowlders, so that they are evidently in part contemporaneous with a glacial period. A number of factors, especially the Chellean fauna of Gower, the presence of *Corbicula fluminalis* at Selsey, and the occurrence of Acheulian-Mousterian implements in the "head," combine to indicate this glacial period as that of the North Sea drift and chalky bowlder clay. On the east coast there are raised marine deposits from just before, during, and just after this glaciation, so that it is probable that in south and west England the raised beach represents the whole duration of the cold period. In such case, the materials would be constantly sorted by the waves, and though large

erratics might occasionally survive from the period of greatest cold, the molluscan fauna of the beach would be that existing when it was finally elevated. On these grounds the raised beaches and associated deposits of south and west England can be tabulated and correlated as follows:

SOUTH AND WEST ENGLAND.	EAST ENGLAND.
1. Bowlder clay of Penrose and scattered erratics.	North Sea drift. Chalky bowlder clay.
2. Raised beach of Chichester and the west.	Marine gravels of March and Holderness. 130-foot terrace of Thames.
3. Estuarine series of Selsey. Marine and eolian sands of Devon with temperate fauna. Chelles fauna of Caves.	100-foot terrace of Thames. Temperate beds of Hoxne.
4. Raised beach of Selsey and Brighton. "Head," Gravelly bowlder clay of Gower.	Middle terrace of Thames. "Warp and trail." Arctic beds of Ponder's End and Hoxne. Hessle bowlder clay.

The Upper Head of Gower may belong to period No. 4 or may be contemporary with the lower terrace of the Thames.

There is no evidence that the south of England and south Wales have ever been below their present level in postglacial (or post "head") times, if we except the faint suggestions put forward for South Devon by Hunt and Rogers (88), but there is abundant evidence that the land stood at least 80 feet higher in the "submerged forest" period. These forests are all neolithic, but seem to approximately fill that period, since both early and late neolithic implement types are represented. The flora is poor, and composed of widespread species, and so gives no definite evidence as to climate. C. Reid considers the submergence to have been fairly rapid, and to have terminated about 3,500 years ago: it has left a tradition that St. Michael's Mount once rose from the midst of a forest.

NORTHWEST ENGLAND.

In northwest England we again find a tripartite division of the glacial deposits. At the base is a hard, stony till with marine shells, overlain in many places by deposits with erratics and occasionally sea shells, but only such as could have been derived from the neighboring bowlder clay; they include the well-known deposits of Moel Tryfaen and Macclesfield. At lower levels these sands and gravels are overlain by second bowlder clay. No evidence has yet been brought forward of contemporary fossils in the sands and gravels, and there is no evidence that they represent more than an oscillation of the ice edge. The lower bowlder clay is in general gray, and gives no evidence of a much greater age than the upper clay.

Very occasionally indications are found of a much older bowlder clay separated from the later clays by a true interglacial period. J. D. Kendall (89) gave particulars of a number of borings at Lindal and Crossgates in Furness, in which a bed of vegetable matter 600 yards long by 300 yards wide was found between upper blue and gray bowlder clay and lower red and gray bowlder clay. The red color of the latter probably represents an old weathered surface. There are a number of similar vegetable deposits in North Lancashire and West Cumberland, which are referred by the author to this horizon, though they are not both overlain and underlain by bowlder clay. The flora of the peaty deposit, according to J. Bolton and Miss E. Hodgson (90), consists of diatoms, mostly of local recent species, with fern spores, *Sphagnum* and leaves and fruit of beech. It is difficult to avoid the inference of its interglacial age.

In eastern Ireland the succession is identical, and we have there further evidence in the relations of the bowlder clay to the raised beaches, that all three members of the tripartite series correspond to the second glacial of England, or the Hessle clay, and similar relations are suggested by the discovery at Egremont (91) of an old sea cliff, indicating a level similar to the present, beneath the "lower bowlder clay" of the tripartite series.

It is difficult to make out the course of events in the period immediately following the last general glaciation of northwest England. Of later date are local moraines in the mountain valleys of north Wales and Cumberland. They have not yet received any detailed study, but B. Smith (92) remarked that there were splendid terminal moraines between 600 and 800 feet on Black Combe, in Cumberland; these probably represent a snow line at about 1,100 feet. This would correlate them with the "large valley glaciers and district ice sheets" of Scotland, which. I shall show, probably belong to the concluding stages of the upper bowlder clay glaciation. No later moraines have been described with a higher snow line, though they probably exist in the highest mountains of Wales and Cumberland.

The sequence of events on the coasts of Lancashire and Cheshire after the formation of the upper bowlder clay is rather obscure. During the melting of the ice the land apparently lay at first below its present level, for the bowlder clay is covered in places by a bed of reassorted gravel, T. M. Reade (93). This was rapidly followed by elevation, and the formation of river valleys below sea level, but Mellard Reade mentions no deposits which he attributes to this stage.

The next stage appears to have been a submergence to about 50 feet below the present level, corresponding to the 50-foot beach of Scotland, to which Mellard Reade and C. E. de Rance attribute a

plane of marine denudation rising inland from 50 feet to about 90 feet and covered by blown sand of the later period. The seaward margin of this plane is formed by a cliff against which the deposits of the 25-foot submergence rest. To this submergence also Reade attributes the "washed drift sand" underlying the lower peat and forest bed and containing remains of hazel. This 50-foot submergence may also be represented by the higher terraces in some of the Lancashire valleys. The evidence for its existence is not entirely satisfactory, and the question would probably repay detailed study.

After this the succession is well marked, being—

1. Lower peat and forest bed.
2. Formby and Leasowe marine beds and Shirdley Hill sand.
3. Lower *Cyclas* clay.
4. Upper peat and forest bed.
5. Upper *Scrobicularia* and *Cyclas* clays.

These do not call for much remark. The lower peat and forest bed begins with a layer of tree stools, resting generally on bowlder clay, in the valleys which intersect the 50-foot plane of denudation. They are overlain by peat up to a thickness of 4 feet. The characteristic tree is hazel; *Ursus spelaeus* has been found in the peat.

The Formby and Leasowe marine beds and associated marine deposits form the lower plain of Cheshire and Lancashire. Their upper limit follows the 25-foot contour with great exactness. The fauna gives no evidence of a climate differing from the present. The Shirdley Hill sand consists of two facies, a marine facies at lower levels, with *Cardium edule* equivalent to the Formby and Leasowe beds, and an æolian facies forming old sand dunes and extending over the upper plane of denudation. The marine beds gradually pass up into the fresh-water *Cyclas* clays.

The upper forest bed rests on these marine and fresh-water beds, and extends to a depth of 40 feet below sea level, indicating an emergence to at least 50 feet above the present level. The trees include oak, pine, hazel, and birch; some of the oak stools have a diameter of as much as 7 feet, so that the climate was far more favorable than now for their growth. The overlying peat reaches a thickness of 12 feet. Its formation appears to have been completed before Roman times.

Passing inland, we find the slopes of the Pennines everywhere peat covered and at present almost devoid of trees. In the peat, however, is a well-marked forest layer, consisting of oak stools to about 1,200 feet, hazel to 1,700 feet, and birch as high as 2,500 feet (94). As a rule at higher levels, the lowest vegetation, resting on the bowlder clay, is of arctic type; this is covered by *Phragmites communis* peat, on which the birch forest grew, and was afterwards replaced by moorland peat. At lower levels the forest bed usually

rests either directly on the bowlder clay or on silts and clays with arctic plants.

The forest bed in this succession evidently corresponds to the superior forest bed of the plains, and to similar beds in Scotland and Ireland; it points to a period when the climate was much more favorable for tree growth. As it falls in a period of elevation, it was probably a period of continental climate.

The horizon of the arctic bed is more doubtful. In this district it has not yet been found to be separated from the bowlder clay by any temperate deposits, but, as well-marked arctic beds occur over temperate peat in the southern uplands of Scotland and in Holderness, it is probably on the same horizon as the latter, and indicates a return of cold conditions.

At this point it will be well to review the general evidence in England for a long interglacial between the formation of the chalky bowlder clay and that of the Hessle clay and other beds of Hessle clay age. Firstly, the surface of the Hessle clay is much more rugged than that of the chalky bowlder clay. The latter forms a level or slightly undulating plateau surface, deeply dissected by the rivers, while the Hessle clay forms a more rugged country with an uneven surface, in the basins of which "meres" are found. The change is very marked in passing from West Norfolk to Holderness.

Secondly, there is the evidence of weathering. The chalky bowlder clay is so calcareous that it always preserves a grayish tint, but at Finchley the soft chalk which it must once have contained has completely disappeared, and only the hard Lincolnshire chalk remains; erratics of this are always rounded, and rarely retain even faint striations, though striations often remain on the hard carboniferous limestone.

Thirdly, there is the evidence of the distribution of the fossil remains of the Quaternary mammals. The distribution of the species of *Elephas* was described, with maps, by Leith Adams (95). *Elephas antiquus* and *E. meridionalis* occur in association only in the Cromer forest bed. *Elephas antiquus* and *E. primigenius* occur associated at a number of points, all outside the limits of the bowlder clay classed as newer, except the cave earths of Cefn and Gower in Wales. *Elephas antiquus* never occurs on the surface of the newer glacial deposits. *Elephas primigenius*, on the other hand, occurs alone over most of England and Wales and the south of Scotland, and is younger than the newer glaciation.

The association of *Elephas antiquus* with abundant *E. primigenius* is characteristic of the "Chelles" fauna, including *Rhinoceros megarhinus*, *R. leptorhinus*, *Hippopotamus amphibius*, and other species. The southern limit of the newer bowlder clays also forms the

northern limit of the occurrence of Chellean and Acheulian implements in locally postglacial deposits. The "Chelles" fauna is thus evidently younger than the older bowlder clay and older than the younger bowlder clay, and as it is highly developed and of a very temperate facies, it must represent an interglacial period between the older and newer bowlder clays.

Fourthly, interglacial conditions, according to C. Reid (96) are shown by the plants in the fossiliferous deposits at Hoxne, Hitchin, Grays, Selsey, Stone, and West Wittering, where beds containing species which now live only in warmer districts are overlain by deposits of a cold or even arctic climate.

GLACIATION OF SCOTLAND.

In Scotland, where the country is more mountainous, the temperature lower and the precipitation heavier than in England, glaciation was proportionately more severe, and we may accordingly expect to find very few traces of any beds earlier than the last general glaciation. Those known can be described in small space. A number were mentioned by the late J. Geikie ("Great Ice Age").

At Clava, near Inverness, is a fine clay containing marine shells of northern species between two bowlder clays. This bed was investigated by Mr. Fraser in 1882 and Mr. Crosskey in 1886, and each of them considered it to be in situ, and indicating a submergence of over 500 feet, as did the majority of a British association committee which investigated it in 1894 (97). The deposit is 16 feet thick and extends for a distance of at least 190 yards in a well-nigh horizontal position. The shells are remarkably well preserved and the deposit is not disturbed or crushed in any way. The fauna is not intensely Arctic but implies colder conditions than the present, except that many of the Foraminifera are now found only in tropical and temperate and not in Arctic Seas. H. Munthe, a Swedish geologist who visited the section in 1896 (98), considered that, while the organisms from the top and bottom of the section are subarctic, those from the middle are temperate, so that the bed shows a complete climatic wave, but no other geologist has remarked this. It is overlain and underlain by tough bowlder clay, neither bed being of the loose moraine type which characterizes the latest glaciations of Scotland. The similar deposit at Cleongart, Kintyre, was also investigated by the British Association committee and by H. Munthe; here the evidence in favor of the deposit being in situ is still stronger. A fine shelly clay rests directly on coarse gravel with a sharp horizontal junction, and overlain by a dull reddish bowlder clay. The shelly clay has been found in section in the sides of Cleongart Burn and Drumore Burn, about a mile apart, and Tangy Burn, 3 miles farther

south. At Cleongart bores were put down showing the continuous horizontal extension of the clay for at least 100 yards, and the committee consider that the bed probably extends more or less continuously from one glen to another. The top of the clay is from 130 to 190 feet above the sea. The Mollusca are northern and much broken; some of them also extend southward, and most are still British. The Foraminifera are in many cases southern. Here also Munthe concluded that the organisms from the center of the deposit are of warmer types than those from the top and bottom.

After the last general glaciation of Scotland there appear to have been local developments of glaciers of decreasing importance. A summary of his investigations in this connection was given by J. Geikie in 1906 and again in 1914 (90). After the melting of the ice of the last mer de glace, the land sank about 100 feet, and there was a recurrence of glacial conditions, forming piedmont ice sheets in the north and large valley glaciers in the south. The sea lochs of the north were largely occupied by glaciers, which calved and dropped blocks in the 100-foot raised beach. The fauna of this beach is arctic. Outside the region occupied by the glaciers in the south, the lowest layer of the peat bogs is an artic plant bed with *Betula nana*, *Salix polaris*, and *Dryas octopetala*. The level of the beach reaches 130 feet in Forfarshire; from this height it diminishes to less than 100 feet.

These deposits are considered by Geikie to represent a complete glacial period, his Mecklenburgian, separated from the last mer de glace by an interglacial, but I can not discover any reference to interglacial deposits which can be referred to this period, though conditions should have been favorable for their preservation. It seems more probable that the moraines and the arctic plant beds represent the concluding stages of the last mer de glace.

This submergence and glaciation were followed by an elevation to above present level, during which considerable peat deposits were formed. At the base is a forest layer with *Betula alba;* above this is *Sphagnum* peat. In many cases, according to Jamieson, these peat beds rest on marl beds containing skeletons of *Cervus megaceros* and *Bos primigenius*. During this period the thick and extensive accumulations of the 100-foot beach were largely removed by the rivers. Alluvial flats were formed at lower levels, on which thick layers of woody peat were formed at and below present sea level.

Renewed subsidence brought about the formation of the 45 to 50 foot beach, which in places directly overlies the alluvial peat just mentioned; moreover, the bottom of this beach is often crowded with leaves, twigs, branches, and occasional trunks of oak, alder, hazel and birch. In the river estuaries the Carse clays were formed. At the head of Loch Torridon well-formed terminal moraines rest di-

rectly upon this beach; elsewhere in the northwest Highlands the raised beach, which is developed at the seaward ends of the lochs, may be absent at the upper ends, possibly because the ice then reached the sea. The snow line at this period stood at 2,400 to 2,500 feet. The submergence was in fact associated with a cold period which, in the peat bogs outside the limits of the glaciers, finds its expression, in artic beds with *Salix herbacea*, *S. reticulata*, *Betula nana*, and *Empetrum nigrum*. The Mollusca of the 45 to 50 foot beach are mostly of local species, with some northern forms. This submergence was followed by a renewed elevation above the present level, accompanied by a drier and warmer climate, which permitted great pines to grow more than 500 feet above the present limits of tree growth in the Highlands. This forest period extended even to the Orkneys, where conifers are not now indigenous, for in the Bay of Skaill occurs a submarine forest with roots of small firs, 15 feet below high water. This upper forest layer is again overlain by *Sphagnum* peat, indicating a return of moist conditions.

In the mountains there appears to have been a very slight recrudence of glacial conditions after the valley glaciation of the 50-foot beach period; Geikie was unable to find any direct evidence as to the horizon of these glaciers, but correlated them with this upper peat layer.

On the coasts there was a renewed submergence of 25 to 30 feet decreasing northward, the beaches of which occasionally overlie a forest layer, which may be either the upper or lower forest layer. These beaches were correlated by Geikie with the upper *Sphagnum* peat and the corrie glaciers, but this seems unlikely, as the beach nowhere contains any suggestion of a fauna of northern origin, and in 1865 its Mollusca were described by Jamieson (100) as seeming "to have more relations to the south than to the north, indicating a climate if anything milder than the present;" the corresponding beach in northeast Ireland has a decidedly warm fauna, but that of Lancashire gives no definite indication of a climate differing from the present. According to J. Geikie, neolithic pine dugout canoes have been found in the Carse clays of the 50-foot beach, but this requires elucidation, for they are stated by Jamieson (100) to have occurred in the deposits of the 25-foot beach.

The succession of events outlined by Geikie is confirmed with this exception of the 25-foot beach by Lewis and G. Samuelsson (101).

The occurrence of the arctic bed overlying the lower forest bed in regions which were not occupied by the glaciers during the valley glaciation (50-foot beach) is considered by Lewis as proof that that glaciation was due to a return of cold conditions after the climate had once become temperate. Lewis has also found the arctic bed be-

tween two forest layers in Ross and in the Shetland Islands, but in the Hebrides the upper forest layer is absent.

Lewis's conclusions about the peat sections were confirmed by G. Samuelsson, a Swedish geologist, who visited Great Britain in 1909 (102). He found the two forest layers separated by the arctic bed and peat at several localities in Scotland. But in his endeavor to correlate the Scottish peat mosses with the Swedish, Samuelsson adopts J. Geikie's classification of the Scottish deposits, and regards the 100-foot beach as contemporaneous with the *Yoldia* sea. He is consequently obliged to correlate the cold 50-foot beach with the warm *Litorina* sea, and to omit the 25-foot beach altogether. But both 25-foot beach and *Litorina* sea appear to fall within the "post-glacial climatic optimum," and to form part of a series of raised beaches with warm fauna occurring on both sides of the North Atlantic, in Greenland, Iceland, and even in the Arctic Ocean, which will be referred to more fully later. The warm, dry upper forestian ends in the bronze age, as does Blytt's warm, dry subboreal period, but as the arctic bed corresponds to the last glaciation of north Europe, the lower forest bed must fall, not in Blytt's boreal period, where Samuelsson puts it, but in the last interglacial of north Europe. Blytt's boreal period seems to be unrepresented in Britain, but this is not surprising, for, as described later, it is also unrepresented in the peat bogs of north Germany.

My own views of the correlation of the Quaternary deposits of Great Britain are shown in the following table:

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Eastern England.	Thames Valley.	South coast and south Wales.	Northwest England.	Scotland.	North Europe.	Archeological periods.
Cromer forest bed.					Tegelen stage.	
Arctic Freshwater bed. North Sea drift. Yarmouth marine sands, etc. Chalky bowlder clay and purple clay of Holderness.	Chalky bowlder clay	Older raised beach. Bowlder clay of Pencoed.	Isolated occurrence of ancient red bowlder clay.	Older bowlder clay.	First glaciation by Scandinavian ice. Chief terrace.	
Marine gravels of Holderness, March, and Clacton. Temperate lacustrine beds at Hoxne.	130-foot and 100-foot terraces. Erosion.	End of older raised beach period. Sands as with temperate fauna at Selsey and elsewhere. Temperate mammalian fauna of Gower.	Temperate beds of Lindall, etc.	Interglacial beds of Redhill, Kilmaurs, etc., and possibly Cleongart and Clava.	Eem beds. Interglacial of *Paludina diluviana* and *Corbicula fluminalis*.	Chellean. Acheulian.
Hessle bowlder clay. Arctic bed of Hoxne.	Middle terrace. "Warp and trail." Arctic beds of Lea valley.	Raised beach of Selsey and Brighton. "Head." Bowlder clay of Gower, etc.	Lower bowlder clay. Midglacial sands. Upper bowlder clay.	Upper bowlder clay. 100-foot beach. Large valley glaciers.	Second glaciation by Scandinavian ice. Middle terrace.	Older Mousterian.
Temperate peat of Holderness.	Erosion.			Lower forest layer and peat.	Skaerumhede series. Interglacial with *Paludina diluviana*.	Younger Mousterian.

Arctic peat bed of Holmpton.	Low terrace.	Possibly upper head.	Arctic peat bed of Penrose.	Arctic peat bed. 50-foot beach. Small valley glaciers.	Third glaciation by Baltic ice. Low terrace.	Solutrean. Magdalenian.
Submerged forest.	Buried channel.	Submerged forest. Pine forest of [illegible]	Lower peat and forest bed.	Peat.	Ancylus period and boreal period.	Early neolithic.
			Formby and Leasowe beds and Shirdley hill sand.	25-foot beach. Peat.	Litorina period and Atlantic period.	Neolithic.
			Upper forest bed.	Upper forest bed.	Subboreal period.	Late neolithic and bronze.
			Upper peat.	Upper peat. Corrie glaciers.	Sub-Atlantic period.	Iron.

7. IRELAND.[1]

A tripartite division of the Irish glacial series has often been claimed, and as often denied. That this division exists in the northeast, east, and southeast of the country I am convinced, from an exhaustive study of the literature, borne out by a few sections I saw in 1914, but there is much question as to its meaning. The lower bowlder clay, as described by Hardman (1875), is very tough and marly, generally blue, gray, or reddish, with angular and rounded blocks, a very considerable percentage of which is often made up of erratics which have almost invariably, when their source of origin can be recognized, been transported from the north or east. In places they contain marine shells and Foraminifera. This bowlder clay is of relatively rare occurrence.

The so-called mid-glacial sands and gravels consist of a more or less horizontal, stratified sheet of gravel with intercalated beds of sand and clay. It is especially well developed in the central plain, under the name of the "limestone gravels." The constituents of the gravels are essentially those of the bowlders in the lower clay, even including marine shells, but the relative numbers often differ. The pebbles occasionally retain glacial striæ, and large bowlders are not infrequent.

The mid-glacial gravels are in places capped by the upper bowlder clay, which is commonly looser and sandier than the lower, and often brown in color; the bowlders are similar to those of the lower clay, with the addition of some from sources in a very different direction, and also with a far higher percentage of local material. Marine shells are almost entirely absent. The upper bowlder clay is frequently capped by gravel terraces and eskers.

It is exceedingly rarely that any indication can be found either of temperate interglacial deposits or of a great difference in age between two bowlder clays. The critical area is that of the "preglacial" raised beach of the southeast. This, as described by W. B. Wright and H. B. Muff (103), extends from Cork to Wexford at a uniform level of about 10 feet above the present beach, possibly descending slightly toward Wexford. In level and in the general sequence of deposits it is so exactly similar to that of south Wales that it is impossible to doubt their correlation, but there is one difference: in southeast Ireland the beach is overlain by two bowlder clays, separated by sands and gravels. The general sequence is:

8. Upper "head."
7. Upper, loose sandy, bowlder clay.
6. Sands and gravels.

[1] In this section dates without numbers refer to Mr. Lloyd Praeger's Bibliography (102).

5. Lower, stiff marly bowlder clay with shells.
4. Lower "head."
3. Blown sands.
2. Raised beach gravels, with erratics from the east.
1. Beach platform.

Unfortunately no fossils have been found in the beach or the blown sands, but, by analogy with Gower and Selsey, there is little doubt that a warm period intervened between the floating-ice period of the raised beach and the glacial period of the lower bowlder clay. The latter must accordingly correspond to the bowlder clay of south Wales, and to the second glaciation of England. This interpretation is supported by the general gray color and nondecalcified state of the shelly lower bowlder clay, which is in direct opposition to the usual characters of the clays of the first glaciation in Europe.

The question then arises, Are there any deposits in Ireland, apart from the raised beach with its ice-borne erratics, which can be correlated with the first glaciation of England? Owing to the intensity of the last general glaciation and the small amount of work done on the Irish Quaternary we can not expect much, and we get very little evidence of such deposits. In Newtown colliery (sheet 137) a bed of highly bituminous peat was found between two beds of bowlder clay, but no further particulars are given. The fact that the peat is described as "highly bituminous" supports its interglacial age. In the neighborhood of Armagh stumps and branches of black oak like that from bogs are stated to have been found in bowlder clay at several places (sheet 47).

Remains of a bowlder clay belonging to an earlier glaciation have possibly been found near Dublin (104). Here we have the usual gravelly upper bowlder clay with rounded stones, mainly limestone, resting on the truncated edges of a series of sand and gravel beds interdigitating with red clay which evidently represents the lower bowlder clay. (The red color of this clay is stated by G. A. J. Cole and T. Hallissy (105) to be due to marine action.) The authors of the Dublin memoir state:

A remarkable feature of the red bowlder clay 300 yards south of the point at which the Loughlinstown stream enters the sea is that it contains large irregular masses of purple clay with sharply defined outlines, which appear to be true bowlders, in some cases sharply fractured, the gaping cracks being filled with sand, gravel, and clay from the surrounding matrix.

These bowlders are nearly identical with 35 feet of laminated purple bowlder clay seen at Kill o' the Grange, which is thus evidently older than the red clay in Killiney, but it does not appear how much older, unless we can read the earlier work of A. Bell into the section here.

Mr. A. Bell (1885–1891) investigated on behalf of a British Association committee the Manure gravels of Wexford and other post-

Tertiary marine fossiliferous deposits of Wexford, Ballybrack (Killiney) and elsewhere. He gives lists of fauna, which show the following relationships:

Extinct, south European, and boreal Mollusca from Ireland.

	Extinct.	South European.	Boreal.	Total.
Wexford	5	5	14	24
Ballybrack	1	2	6	8
Bowlder clay and mid gravels	0	0	10	10

The southern species at Ballybrack are *Woodia digitaria* and *Pecten glaber*. He describes the section at Killiney Bay as an older drift of "large and small rocks, limestone, quartz, schists, and granites (many of the limestones being beautifully striated), intermixed with thick beds of sand, often tilted at an angle of 70° to 80° to the beach beneath which they pass, reappearing at intervals near the Shanganagh and Bray Rivers."

It is overlain by the middle drifts—loose sands, gravel, and occasional large blocks of granite and quartz. He concluded that the Wexford gravels are immediately preglacial and that the Ballybrack fauna is intermediate between that of the Wexford beds and that of the bowlder clays and midglacial gravels. Whatever we may say to the former conclusion, there seems little doubt that the Ballybrack fauna is older than that of the lower bowlder clay. But the Ballybrack fauna is associated with beds which must have been derived from an earlier glacial deposit, possibly the purple clay of Kill o' the Grange. Altogether, this seems strong evidence for an interglacial period in eastern Ireland.

Very little is known as to the depth of the preglacial river channels of Ireland, but the few borings available show that the drift-filled valleys extend considerably below present sea level. A boring in the Lagan River at Stranmillis, 2 miles above Belfast, proved bowlder clay at −60 feet, so that the sea level must have been at least 70 feet lower than now when the valley was excavated. At Dublin the drift-filled valley of the Liffey shows that in preglacial times the land must have stood somewhat above its present level. At Cork the minimum estimate of the preglacial elevation is over 200 feet.

Of later date than the general glaciation of Ireland are the local moraines left by mountain and valley glaciers, as in Scotland. The best developed of these which I had an opportunity of studying were those of the Barnes River glacier in Barnesmore Gap. This gap is a

U-shaped, obviously glaciated valley extending northeast and southwest between Croghconnellagh (1,724 feet) and Barnesmore (1,491 feet); its floor is very flat and is occupied by an alluvial strip in which the Lowerimore River meanders. The Barnes River has cut a narrow V-shaped gorge in an old, rounded glacier valley which enters the gap at right angles; the glacier was banked up against the opposing flank of Barnesmore and spread out along the gap. To the northeast the latter soon widens, but to the southwest the ice was very confined and extended for about 2 miles. On this side it has left three terminal moraines, in addition to the lateral moraines against the sides of the gap. Of the terminal moraines the outermost and innermost are best developed and extend across the gap in crescent form, the convex side outward. The inner moraine is double. These moraines consist of granitic sand with occasional blocks and bowlders of granite and fragments of schist; scattered over the surface are rounded and irregular bowlders of granite. The outer and inner moraines are cut through by the stream and extend on either side of it; the middle moraine is much less developed, and extends obliquely down the valley on one side of the stream only.

From the literature of the subject I had believed that these moraines must all belong to a later recurrence of glaciation, but the appearance of the moraines does not quite bear this out. The two inner moraines are very rough and fresh looking, but the outer moraine is worn and rounded, and is not dissimilar in contour to the drumlins outside the gap. It gave me the impression of a much greater age than the innermost moraine, and it seems probable that here, as in Scotland, the last general glaciation was quickly succeeded by local glaciers. The inner moraines, on the other hand, may correspond to a later cold period for which there is independent evidence.

Other instances of local glacier moraines have been described in the Survey Memoirs and elsewhere (see Ll. Praeger's Bibliography), of which I will refer to one only. In Glenclody, Leinster Mountains, two distinct moraines occur, of which Mr. Kinahan says, "The inside of the smaller moraine is very well marked in places, being nearly a perpendicular wall from 20 to 40 feet or more in height, and having the appearance of a huge Cyclopean wall" (sheets 148 and 149, 1887). This evidently belongs to the latest period of valley glaciers.

RAISED BEACHES AND ESTUARINE DEPOSITS.

In western Scotland, as already described, J. Geikie and others have found raised beaches attributed to three stages, the 100-foot beach, the 50-foot beach, and the 25-foot beach, and we naturally expect these to occur again in northeast Ireland; the two latter un-

doubtedly do so, but with regard to the 100-foot beach, Mr. W. B. Wright states that it is apparently entirely unknown in Ireland. There are, however, a few traces of its occurrence.

On the Horn, west of Dunfanaghy, opposite Tory Island, is a well-developed rock shelf with some flat stones and pebbles, backed by an old deposit of blown sand, now cemented into sandstone in places. The height of the shelf is about 70 feet; sand was banked against the old cliffs for another 20 feet or so. Above the shelf the rocks were not water worn. Just above Templebreaga Arch there was a distinct shelf visible in section. In places at the level of the shelf was some sand bedded at a low angle, the stratification planes marked by pieces of flat shale.

Farther west I know of no traces of this beach, but the country has not been thoroughly explored. In southwest Donegal I could find no trace of it whatever. East of Horn Head, Professor Hull mentions a beach at a height of 75 feet at Malin Watch Tower, in Inishowen, and in his "Report" General Portlock refers to three sets of old sea caves in the chalk cliffs of County Antrim, at heights of 12, 25, and 100 feet. South of this the 100-foot beach appears to be entirely wanting, and this is doubly strange because the neighborhood of Belfast abounds in quiet sea loughs suited for its preservation, which have been thoroughly explored. I will return to this point later. At Dublin a rock shelf which occasionally appears at a height of 25 feet may be the representative of the 100-foot or 50-foot beach of Ulster, since the 25-foot beach has descended to a level of 15 feet by the time it reaches Dublin and this shelf is much older. It may be preglacial, but Kinahan stated (1878) that "About 35 years ago or more (i. e., 1840) it (the 25-foot beach) was very conspicuous along the cliffs (near Kingstown), but all traces of it have since been obliterated; also in places at Bullock, Dalkey Sound, and at the north end of Killiney Bay.

A glacial flood-gravel terrace bordering the coast in the loughs of Londonderry district may be referable to the 100-foot beach. According to Mr. Kilroe it gradually rises inland from about 50 to 125 feet, averaging about 75 feet above sea level. He says, "The materials have evidently been distributed by flood waters issuing from receding glaciers over the valley floor and the low ground bordering the coast during the final disappearance of ice from the regions." It is separated from the present shore line in many places by the 25-foot beach, which terminates against it in a well-marked cliff. At the mouth of the glens of the Muff and Castle Rivers are great alluvial fans of fine sand and clay at a height of 50 feet above the sea.

Beaches at a level of 30 feet or less above the present high-water mark are of far more extensive occurrence. Often they form flat plains a mile or more in width, which may constitute the necks con-

necting former islands with the mainland; the neck of the Hill of Howth is a notable example. Reference is made to these raised beaches in many of the Geological Survey Memoirs dealing with maritime districts. The 25-foot beach attains its greatest height at Malin Head, where it is about 33 feet above high-water mark; north of Londonderry it stands at 32 feet, in Lough Foyle and along the coast of Derry and Antrim about 25 feet. In sheets 20, 21, 28, and 29 the maximum height attained seems to be 15 to 20 feet, including the well-known bed at Larne. At about this height well-marked, shelly, raised beaches extend down the east coast; at Dublin, the level is 10 to 15 feet, and in the Counties of Wicklow and Wexford it ranges from 12 to 6 feet, very conspicuous in places.

On the south coast we have no mention of a postglacial raised beach except at Cork, where in the quieter channels a grass-grown flat backed by an old cliff a few feet above present high-water mark may represent this feature. On the flat occur kitchen middens. The only points on the west coast where any vestige of a raised beach is seen are Drumcliff Bay, near Carney, County Sligo, where a beach-like bed 6 to 7 feet above high-water mark contains remains of oysters, clams, and periwinkles (Memoir sheets 42 and 43, 1885), and near Sligo (Memoir sheet 55), where a "silty bed containing cockles" lies appreciably above high-water mark; and the middle island of Aran, where a shell-bearing beach is recorded by Kinahan, and at the mouth of the Kenmare River, in County Kerry, where there is a thin bed of oysters and other shells just above high-water mark (Memoir sheets 182, 183, and 190). There is thus a striking decrease in the height of this beach from northeast to southwest.

The molluscan fauna of the 25-foot beach of northeast Ireland has been studied by Mr. Lloyd Praeger (1896); he finds a complete absence of arctic species, and only three of northern type, while nine species are of marked southern type. In the present seas of the district the numbers are four northern and three southern. This indicates that the climate was somewhat warmer than the present, instead of being colder, as it was when the higher beaches were formed.

Below the level of the 25-foot beach in northeast Ireland are numerous other beach terraces extending down to high-water mark. Among these a 15-foot beach is often distinguished; in fauna and general characters it is not very different from the 25-foot beach and is probably very little later. Kinahan (1878) supposed it to be separated from the latter by a 30 to 40 foot elevation, and referred the Kilroot gravels to the 15-foot beach, since they contain implements considered by Mr. Du Noyer as younger than those from Magheramorne and Larne. In the river valleys the 25-foot beach is often continued as a gravel terrace 25 feet above the present level of the water, and evidently due to the same submergence. By anal-

ogy, we may correlate the extensive sand and gravel terraces and plains of the River Foyle near St. Johnstown at levels of 50 and 75 feet with the two higher beaches. The Belfast section, to be described next, however, leaves no room for such an elevation.

A far more complete record of the changes from the cold of the glacial period to the warm conditions of the climatic optimum and back to the present climate and level in the Belfast district is given by dock excavations and other sections in the estuarine clays and sands. These have been described by Mr. Lloyd Praeger, in a very elaborate memoir (1892). The best section is that exposed at the Alexandra Dock, Belfast, which is as follows:

9. Surface clays, 6 feet 6 inches; depth below high-water mark, 4 feet 6 inches to 11 feet.
8. Yellow sand, 2 feet; depth below high-water mark, 11 feet to 13 feet.
7. Upper estuarine clay, 6 feet; depth below high-water mark, 13 feet to 19 feet.
6. Lower estuarine clay, 6 feet; depth below high-water mark, 19 feet to 25 feet.
5. Gray sand, 2 feet; depth below high-water mark, 25 feet to 27 feet.
4. Peat, 1 foot 6 inches; depth below high-water mark, 27 feet to 28 feet 6 inches.
3. Gray sand, 2 feet; depth below high-water mark, 28 feet 6 inches to 30 feet 6 inches.
2. Red sand, 4 feet; depth below high-water mark, 30 feet 6 inches to 34 feet 6 inches.
1. Reassorted bowlder clay, base not reached, 15 feet; depth below high-water mark, 34 feet 6 inches to 50 feet.

The same series though less complete is met with at many points along the coasts of Counties Down, Antrim, and Derry. In drawing conclusions from it we must use the principles set out in the introduction showing the relations of the color of deposits to the conditions under which they were formed. The sands 2, 3, and 5 are evidently marine, derived from the underlying bowlder clay; the gray color of Nos. 3 and 5 would lead us to infer that they were formed under colder conditions than No. 2; these cold conditions are confirmed by a study of their fossils. At Belfast and most other localities these are limited to a few starved Foraminifera, but from the gray sand underlying the estuarine beds at Larne were obtained a number of fine examples of the northern shell *Crenella decussata*, which still survives, though rare, in Larne Lough. The same species occurs, but very rarely, in gray sand beneath the estuarine clays at Magheramorne. A gray, sandy silt, with *Salix herbacea* and *Lepidurus (Apus) glacialis*, which occurs in the same relative position in the Isle of Man, is probably on the same horizon, whose most westerly known occurrence is probably the 20 feet of a very fine, grayish sand, without fossils, below stratified gravels in a section in the Faughan

River, in the south of Inishowen, the whole section being here above high-water mark.

The peat bed between the gray sands is described by Mr. Lloyd Praeger as "the first bed still extant showing the ushering in of temperate conditions;" it contains a flora of marsh plants, sedges, flags, and rushes, with the fruit and branches of hazel, alder, oak, willow, and Scotch fir. On the upper surface of the bowlder clay and in the peat, remains of *Cervus magaceros* were found. At Belfast it is 27 feet below high water and at Downpatrick, in the Quoyle estuary, it is far below low water, but at Tillysburn, Holywood, Ballyholme, Carrickfergus, Glenarm, Ballintoy, and Portrush it outcrops between tide marks. It is by no means certain, however, that all the forest beds exposed on the shore are on the same horizon as the Belfast bed; some of them may be later.

Above the second bed of gray sand occurs the lower estuarine clay, or *Scrobicularia* zone; essentially a littoral clay, typically brownish blue, somewhat sandy, containing abundant *Zostera marina*, and a vast number of shells of a few species which live between tide marks. The same bed occurs at several other places on the northeast coast of Ulster. It is always found below tide level, and it indicates that during its formation the land stood about 10 feet above its present level, and was slowly subsiding. The climate does not appear to have differed from that of to-day.

In places, as at Larne, the lower estuarine clay is overlain by the gravels of the 25-foot raised beach, but at Belfast, and also at Magheramorne and Downpatrick, the place of the latter is taken by the upper estuarine clay, a very pure and unctuous light blue deposit, probably black before exposure to the air. It contains a very rich and well-preserved fauna, chiefly of shells from the laminarian and coralline zones, and characterized by the bivalve *Thracia depressa*, whence the bed is termed the *Thracia zone*. A full list of the fauna, with remarks on the distribution of species, is given by Mr. Lloyd Praeger (1896). The shells are mostly of large size, and include species which are not now known from the shores of Ulster. *Rissoa alba*, very common in the clay, is only known as a recent species from Bantry Bay, whereas *R. parva*, the present common form, is rare in the clay. *Jeffreysia opalina*, practically unknown, living in Irish waters, is common, and also large specimens of *Odostomia minima*, now rare and dwarfed. As a whole the fauna, like that of the raised beaches, indicates a rise of several degrees in the temperature of the sea water, while the land must have stood somewhat below its present level.

After this period of depression, a slight elevation set in, resulting at Belfast in the formation of 2 feet of yellow sand containing many shells, including *Thracia* and *Scribicularia*, evidently washed out of

the underlying estuarine clays. In the Bann Valley the *Thracia* clay was removed and brownish river sand deposited in its place. Elsewhere on the coast the *Thracia* clay is overlain by blown sands. This elevation carried the land about 6 feet above its present level, and the final subsidence has resulted in the accumulation along the shore of black littoral clays ("slobland"), crowded with *Mya arenaria*, *Cardium edule*, and *Mytilus edulis*. At Belfast their thickness is 6 feet 6 inches.

Nowhere else in Ireland have we a section approaching this in completeness. All round the coast drowned and alluvium-filled valleys, submerged forests, and "slobland" point to a postglacial subsidence, which at Cork must have exceeded 50 feet. At many points on the west coast, peat beds with tree stools in situ can be seen to pass below low-water mark. But in the absence of more complete sections it is very difficult to "place" these deposits in the postglacial sequence.

Near Dublin the 15-foot beach (i. e., 25-foot beach of Belfast) lies on submerged peat, and is therefore younger, as in Ulster. In the estuary of the River Slaney, County Wexford, Kinahan (1875) described the following section:

Mud, 16 feet; surface at sea level.
Peat, 5 feet.
Gray muddy stuff, 1 foot 5 inches.
Marl (bowlder clay).

The peat shows that the land must have stood at least 30 feet higher than at present, and this is confirmed on the neighboring sea-coast. No particulars of the "gray, muddy stuff" are given, but possibly it corresponds to the gray sand of the Belfast section. The "mud" corresponds to the estuarine clays and overlying deposits; near the end of the time when it was accumulating there seems to have been a slight rise of the land, as the upper stratum is highly impregnated by iron and separated from the lower by a layer of shells.

It is difficult to correlate the superficial formations of the interior with these estuarine and marine deposits, owing to the lack of common elements. Here again the cold period represented by the later corrie and valley glaciers offers a useful horizon. This is well seen in the Ballybetagh bog, near Dublin, described by Mr. W. Williams (1878). The section is as follows:

6. Peat with oak and alder, 2 to 8 feet.
5. Grayish clay, 2½ to 3 feet.
4. Brownish clay, with *Cervus megaceros* and plants, 3 to 4 feet.
3. Yellowish clay, largely composed of vegetable matter.
2. Fine, tenacious clay, without stones.
1. Bowlder clay.

The section lies at a height of 300 feet in a small valley between some outlying granite hills. The surface is now pasture. No. 1 was referred by Mr. Williams to the lower bowlder clay, but it contains a large number of limestone pebbles, and is, therefore, on the horizon of the upper bowlder clay. (2) is simply rewashed bowlder clay. (3) contains so much vegetable matter that it can hardly be called a clay. From the total absence of any tenacious clay like (2), Mr. Williams infers a decrease of the rainfall. (4) is a lacustrine clay containing a considerable proportion of vegetable matter, interstratified with seams of clay and fine quartz sand. According to Mr. Williams it indicates genial or temperate conditions like the present. Numerous remains of *Cervus megaceros*, chiefly skulls with antlers, occur resting on the surface of the plant bed No. 3, and at various levels in the brownish clay. Near the top of the latter they are often found broken, and in one case antlers found embedded in the top of the brown clay and protruding into the grayish clay No. 5 were scored "like a striated bowlder."

This grayish clay, or loam, as I should call it, consists exclusively of mineral matter derived from the disintegration of granite. During its formation there can have been no soil on the neighboring hills, and weathering must have been intense. It is practically unfossiliferous, but Mr. Williams records finding a reindeer's horn in it. From all these characters it is difficult to escape from his conclusion that it represents a very severe climate. Since it is separated from the horizon of the upper bowlder clay by more temperate deposits, it must represent a return of cold conditions, after an interglacial period.

A similar section occurs at Craggah, near Ballah, County Mayo (Williams, 1881), lacustrine beds with Irish elk being overlain by a chocolate-brown detrital clay derived from the wearing down of the coal measures, the whole being covered by bog.

Underlying the peat bogs over a large part of the central plain of Ireland are white or blue lacustrine marls, which Mr. Williams attributes to the same cold period, on the ground that abundance of moisture would dissolve and subsequently precipitate great quantities of carbonate of lime, but this seems erroneous, for the marls are really shell marls, and presumably a high temperature is more favorable to fresh-water shells than a low one. Remains of Irish elk are frequently recorded from these marls (those described as from the base of the peat bog are in most if not all cases really from the marl) and this also seems to place them on the horizon of the lacustrine clay of Ballybetagh.

The memoirs of the Geological Survey contain many descriptions of postglacial detrital deposits which seem to demand a far more

severe climate than the present. I have already mentioned the grounds on which I regard the "head" of the south coast as belonging to this recurrence of cold conditions rather than to the period of the upper bowlder clay. Similarly many coarse river terrace gravels and delta deposits probably belong to the same period, though proof is difficult. I will merely pick out a few striking examples. I have already mentioned the gravel terraces near Londonderry. Some of the post-upper bowlder clay terraces of the Liffey and other rivers are very coarse, indicating torrential action; these would probably repay further investigation. The remarkable frequency with which tree stools, especially oaks, are rooted directly in lacustrine marl, without any intervening marsh deposit, suggests some break in the succession, the lake's outlet being cut down and its bed drained under conditions not favorable to vegetation.

In Killimor Bog, County Galway (Memoir sheets 115 and 116, 1865), peat rests on lacustrine marl and is covered by alluvium. The originally horizontal lamination of the marl has been crumpled, as though by a powerful horizontal pressure, and the surface planed smooth, before the formation of the peat. This strongly suggests the "warp" of river silts, which is due to floating ice.

The uppermost superficial deposit over a great part of Ireland is peat, which covers one-seventh of the country to a depth ranging up to 50 feet. Peat bogs are of two main kinds, lowland or red bogs, mostly composed of the accumulated remains of marsh plants, growing in a lake or swampy hollow, and mountain bogs, much tougher and of slower growth, formed by a close mat of heath plants which can extend up or down quite steep slopes, even over porous rock, as well as occupying flat hilltops. In the west of Ireland the mountain bogs descend also onto the plains, displacing the red bogs. The two chief points of interest are the buried forests and the archeological remains.

Remains of oak, fir, pine, hazel, and other trees occur everywhere in the bogs, including branches and fruits and also stools rooted in the underlying bog or rock. Mr. G. H. Kinahan (e. g., 1878) stated very positively that these tree remains form two well-marked forest horizons, one at the base of the peat and the other some feet above it, but this has frequently been contradicted. My own conviction is that the two horizons certainly exist in some bogs, but that in some others the conditions were not suitable for its development, while as regards the great majority of the bogs we are totally ignorant. I examined a number of peat cuttings in County Cavan, but could not find one which went down right to the bottom of the peat near the center of a basin. In response to my inquiries I was always informed by the cutters that in the middle of the bogs they never cut to the bottom because the peat is too wet there; the latter fact was

obvious in the cuttings already made. Consequently none of them knew of oak below fir in the middle of the bogs. But where a bog is being cut on the edge of a basin, oak is found, and seems to extend some way down the sides, in places being rooted in lacustrine marl. For these reasons I conceive that Kinahan finding oak stools rooted in marl on both sides of a basin and extending below the level of the uncut peat, concluded that those on either side were both parts of one forest which extended completely across the basin. The statements in some of the Geological Survey Memoirs that stools of oak were found "at the bottom" of the bogs are probably only to be interpreted "on the floor" of the bogs.

While there is some support for the two forest layers in the lowland bogs, there seems very little in the upland bogs. Where a rough, hummocky rock surface is covered by a bog there is in or on the bog a very well-marked horizon of stools, which extends onto the bare rock where the latter rises above the level of the old forest, but I could not find a single instance in which tree stools rested on rock below the level of this bed. Nor, so far as I am aware, have any such been described.

The upper forest layer is an exceedingly definite horizon all over Ireland. The surface of the peat dried and remained firm for a period probably of more than a thousand years; on it there grew a forest of pines. Some of the stools show 200 annual rings, and they lie so closely together that several generations must be represented. Even in the west of Ireland, where no trees grow now, well-grown forests extend up the hills to a height of about 500 feet, and isolated trees to nearly 2,000. After a time, peat recommenced to grow, killing the trees, and reached a thickness of from 20 to as much as 50 feet, though almost everywhere the upper part has been removed for fuel. In the west and in the central plains the peat is still growing on the cut surfaces, but in the east it has ceased to increase and is being desiccated.

In the old, submerged land surfaces which are common all round the coast of Ireland, the upper, or fir forest commonly forms the basal layer, overlain by a small thickness of peat where this has not been removed, and this enables us to correlate the fir forest with the post-raised beach elevation. On the raised beach flats, peat usually occurs with a layer of stools of oak, fir, or hazel at the base. This is supported by the frequent appearance of stream sections in which a peat bed with fir stools at the base is overlain by river alluvium, the deposition of which must be due to a raising of the base level.

It is the fir forest layer also which is chiefly of interest in connection with the archeological remains found in the peat. These belong to the neolithic, bronze, and iron ages, and it is the neolithic which are chiefly associated with the forest horizon. They indicate

a relatively high stage of civilization. In 1833 a two-story log house surrounded by an inclosure was found in Drumkelin Bog, County Donegal; it was 12 feet square and 9 feet in height, and a roadway led to it across the bog. Both house and roadway were entirely constructed of oak, no fir being used. With the hut were found a stone chisel and a flint arrowhead. Beneath the floor were 14 feet of bog, and above the floor 26 feet. Other roadways or "cashes" have been found, e. g., at Ballyalbanagh, County Antrim, above 4 feet of black turf and below 5 feet of flow bog; at the base of the black turf were oak logs and stools, and on the level of the road fir stools. None of the latter were beneath the road, which was built entirely of oak. A neolithic ax was found near the road. These discoveries of an advanced neolithic civilization on the forest layer confirm our inference that it is younger than the 25-foot raised beach, for in and on the latter are found numerous neolithic implements of a far more primitive type. Probably the peat under the forest layer representing moister conditions corresponds to the 25-foot submergence.

Many fine relics of the bronze and early iron ages have been found at various depths in the peat; a number of lunulae or collars of gold, bronze swords and daggers and a long rapier of bronze. In a bog at Cromagh, Armoy, County Antrim, was found a woolen garment, with a bronze pin, celt, gouge, razor with leather case, and an ornament of horsehair. Bodies dressed in old-fashioned woolen garments have been found from time to time.

In interpreting the meaning of this well-marked peat bog succession, we must remember the peculiar conditions of peat formation. The basal layer of oak stools, rooted in the solid rock or even in lacustrine marl, is merely what we should expect, for on any ordinarily well-drained ground the water flows off too rapidly for the growth of peat. The ground is therefore first occupied by a forest; if the region is a lough shore, the trees grow to the water's edge, and as the cutting down of the outlet lowers the level of the water, trees grow at lower and lower levels, encroaching on the old lake deposits.

The next stage is the formation of leaf mold and perhaps the prostration of a few trees; this checks the drainage, and peat mosses grow up between the trees, finally choking them and entirely occupying the site. In the case of a lake basin the same result might be arrived at by marsh plants choking the waters and finally rising above their level, and so killing the neighboring trees, but this must be more local. So far there is no reason to assume a change of climate; the desiccation of the peat sufficiently for its use as a dwelling place for man, and for the growth of trees is another matter. The very widespread nature of the phenomenon is proof that the change was not due to artificial draining, and the same fact, as well as the very

variable thickness of peat beneath the forest layer, shows that another cause often cited is equally insufficient, namely the upward growth of the bog until it could not longer raise water to its surface by capillary action. The only possible explanation seems to be a general climatic change toward drier conditions. There are two other points which support this. The first is that during the forest period the firs in the lowlands attained a size which is not reached by any existing Irish firs, and extended up the mountains to a considerably greater height. I counted over 50 annual rings in a tree stool at 1,200 feet on Croghconnellagh, whereas they will now scarcely grow even at sea level in the region; even greater heights are attained elsewhere. To make this possible the climate must have been considerably warmer as well as drier than now, probably by 3° F.

The second point which supports the dry-climate theory of the fir forest is the frequent occurrence of trees apparently in situ beneath the surface of fresh-water loughs. A good example is Lough Toome in southwest Donegal and a small lough to the east of it. There was very little peat on the shores of the lake, and the trees appear to be in situ, though when they grew the water surface must have been at least 2 feet below the level of the present outlet, which, so far as I could see, had never been deeper. Mr. Wynne (1867) has described similar occurrences in Lough Arrow, near Boyle, and in the bed of the River Garwagne, just before it flows over a rock bar. Both localities are in Connaught. He attributes the occurrences to erosion of the peat on which the trees grew, allowing them to settle slowly in the position of growth; this erosion of the peat is still going on. Several cases in northeast Donegal, where the phenomenon is very widespread, were investigated by G. H. Kinahan (1866–7). He concluded that the stools are in situ, but that in some cases growth of peat may have choked the drainage, and caused the submergence of the stools, though in others, such as Pollet Lough, Kindrum Lake, and depressions about Lough Aweel there is no apparent old exit below the level of the present one. In one of the Lough Aweel depressions bog oak is found at the greatest depth. Most of the loughs in which these submerged stools are found are shallow upland basins with a small drainage area, and in May, 1914, when I saw them, some of them were suffering severely from drought, so that if the present climate became hotter and drier they would more or less completely disappear, allowing trees to grow below the level of the outlet.

The fir forests were killed by a return of moist and cold conditions, causing a fresh growth of peat. The climate seems to have been more severe than during the earlier period of peat formation, for many hill regions were now peat covered for the first time. On Copped

Mountain, near Enniskillen, and elsewhere tumuli or cairns referred to the bronze age have been built and subsequently covered by several feet of peat; this shows that the change occurred not earlier than the bronze age. For the reasons stated above, peat formation probably commenced earlier in the forests than on the bare ground. Recently the climate appears to have become drier, for in eastern Ireland the bogs are ceasing to grow.

From the raised beaches, the estuarine and lacustrine deposits, and the peat bogs I have now constructed a fairly connected account of the history of Ireland since the melting of the last great ice sheet. The remaining superficial deposits can be dismissed briefly; they fit readily into the sequence and so far entirely confirm it, but they provide little that is new.

The Irish caves have been frequently investigated and have added to the list of Irish Pleistocene fauna, but their bearing on the climate is small. More important are the sand dunes which occur at very many places on the Irish coasts, and are noted for the neolithic hearth floors with flint implements, pottery, etc., which are exposed among them from time to time. Detailed descriptions of these prehistoric remains were given by Mr. W. J. Knowles in 1889, 1891, and 1895; the implements are neolithic in age, and the presence of pottery points to a fairly late section of neolithic times. The sand dunes frequently rest on the flats of the 20-foot beach, and are consequently younger than that submergence, and they probably originated in the fir-forest period, when both elevation and dryness were favorable to their formation. But to render them habitable they must have been fixed by vegetation, probably during the moist period of the upper peat. The subsequent readvance of the sand may be due to the slight desiccation which has caused the cessation of growth in the bogs of east Ireland.

LAND TO THE WEST OF IRELAND.

The almost complete absence of postglacial raised beach deposits over the greater part of western and southern Ireland suggests that the district was elevated to such a height that even the submergence of the 100-foot beach failed to leave any traces above the present shore line. This elevation was also inferred by Maxwell Close (1867) from the configuration of the deeply indented west coast. The contours of the latter at a depth of 200 feet present far more resemblance than the present shore line to the east coast of Ireland. The central plain of Ireland also is lower in the west than in the east by about 200 feet. He also pointed out that the axis of movement of the "Irish ice," which passes very near to the coast in southwest Donegal, necessitates a considerable extent of land to the westward. Recently Messrs. Cole and Crook (106) have remarked that rocks indi-

cating subaerial erosion are developed on the Porcupine Bank and other points off the west of Ireland, and banks of dead shells of littorial type occur elsewhere on the continental shelf; the sea bottom here presents an interesting contrast to the drift-encumbered floor of the sea between Scotland and Ireland.

If the tilting which causes the 25-foot raised beach to descend from 30 feet at Malin Head to sea level at Donegal, were prolonged for 200 miles to the southwest, it would result in an elevation there of nearly 90 feet.

I have already alluded to the submerged peat frequently observed to extend below the level of spring low tides on the west coast, and pointed out that this elevation must extend well into the neolithic period; there is other evidence which brings the final subsidence down to a much later date. The Rev. W. Kilbride, proved that at Tramore, on Aran Island, human habitations extend below spring low tides level, and the ancient annals have accounts of the "bursting forth" of lakes, so that fresh-water loughs became arms of the sea, owing to the sinking of the intervening land. Galway Bay is mentioned as an example. (Kinahan, 1878). That this is not merely a case of marine erosion is further shown by the case of Lough Corril, which according to tradition was formerly only one-half of its present size—this reduction would have been effected by raising it 15 feet. Finally we have the tradition of Atlantis, the island to the southwest of Ireland, whose mythical existence thus finds strong support.

East and northeast of this area of high land lay the region of maximum submergence in late glacial times, but it is difficult to explain the apparently abrupt disappearance of all the beaches. The 100-foot beach has not been traced west of Horn Head, where it is about 70 feet above the sea. Probably the boundary between the regions of elevation and of considerable depression was an unstable zone in which the shore never remained at one level long enough for the development of noticeable rock shelves or terraces. In any case the north coast of Donegal has not yet been examined in sufficient detail.

Even more remarkable is the fact that no record has yet been made of the high level beaches in the district around Belfast, although the Geological Survey has recently reexamined the superficial geology. It is possible that the beaches were formed there and subsequently removed by denudation, but the number of sheltered loughs and estuaries renders such complete removal improbable. The alternative is that the beaches were formed and still exist, but the resultant of subsequent movements has left them at sea level. That this is the case we have strong evidence in the occurrence of the gray marine sands of the Belfast district, already described; like the

beaches, they are of approximately the same age as the cold periods, and they are shallow water sands at present a little below sea level at Belfast, but rising above it farther west.

Curiously enough, this change in the relative levels of Belfast and Malin Head has also left a trace in tradition, namely that Lough Neagh was formerly smaller, but its shores subsided, carrying human habitations below the waters. The area was the scene of great volcanic activity in Tertiary times, and the traditional subsidence may be the last of several in postglacial times which carried the 100-foot beach of Belfast down to sea level.

SUMMARY.

I. *Glacial.*—Raised beach of South Ireland. Bowlder clay of Kill o' the Grange and gravels of Ballybrack.

I. *Interglacial.*—Peat of Newtown.

II. *Glacial.*—1. Lower bowlder clay. 2. Midglacial gravels. 3. Upper bowlder clay. 4. 100-foot raised beach. 5. Moraines of large valley glaciers.

II. *Interglacial.*—Lacustrine marls, etc., of Ballybetagh, etc., with Irish elk. Earlier submerged forest (northeast Ireland).

III. *Glacial.*—Moraines of small valley glaciers. Detrital deposits of Ballybetagh, etc. "Head" of south coast. 50-foot beach and gray sands of northeast coast. Arctic bed of Isle of Man. Lower peat bed.

Warm wet period.—25-foot raised beach with southern fauna.

Warm dry period.—Pine forest. Extension of trees up mountain sides. Elevation and formation of later submerged forest.

Recent period.—Upper peat.

8. THE POSTGLACIAL HISTORY OF THE LAND AREAS OF NORTHERN EUROPE.

After the melting of the ice of the last glacial period in Germany, north Russia, and the Scandinavian countries, various terrestrial deposits were formed which throw light on the subsequent climatic history of the district. Chief among these are the peat bogs, which have been studied in great detail, in Norway by J. Holmboe and P. A. Oyen, in Sweden first by A. Blytt, later by Gunnar Andersson and R. Sernander, in Finland by H. Lindberg, and in Germany by J. Stoller and C. A. Weber.

It is in Sweden that the question of the existence and meaning of "forest layers" in the peat bogs has been most critically discussed. The succession made out by A. Blytt (107) was as follows, the oldest period being at the bottom:

Sub-Atlantic, wet.
Subboreal, dry.
Atlantic, wet.
Boreal, dry.
Subarctic and arctic.

These periods are adopted by Sernander (108). He correlates the boreal period with the *Ancylus* lake and the Atlantic, subboreal, and sub-Atlantic periods with the *Litorina* period. While the ice was retreating from south of Scania to the Fjalls (the mountains about latitude 64°) it was followed by an arctic flora of xerophilous type, which Sernander regards as the equivalent of the Yoldia period, but as soon as the ice edge passed the Maler-Hjalmar Valley this flora for the most part disappeared, and the ice—which at this period was melting rapidly—was followed directly by *Sphagnum* peat. The transition period was marked by *Betula odorata* and *Populus tremula*, but the characteristic tree associated with the peat of early *Ancylus* time is the pine. The late *Ancylus* period was marked by widespread forests of birch (*B. alba*) which have left a well-marked layer of stools in the peat bogs. To the evidence of the tree stools Sernander adds that of a snail, *Helix edela* (*H. tenuilabris*), found in sand of "boreal" age in a boring at Ystad, but not now living nearer than southeast Europe.

Resting on the tree stools of the birch forest is generally another layer of *Phragmites* peat, often giving place to lacustrine marls. This is the peat of the Atlantic period. It is followed by another layer of stools, this time of *Pinus silvestris*, forming the subboreal period. This is finally replaced by *Cladium* or *Sphagnum* peat, which is still forming. In the lake basins the stools of *Pinus silvestris* often occur on lacustrine marl, and are normally covered by the present waters of the lakes, being visible only in very dry seasons.

Sernander considers that the warm climate of the boreal period extended into the sub-Atlantic and subboreal times, since subboreal peats, comparatively late and near sea level, contain plants of a more southern type than any now living in the district, and hazelnuts occur in peat far north of the present limit of the hazel, while L. von Post (109) has found the pine in beds of Atlantic and subboreal age above its present upper limit in the mountains of southern Sweden.

The researches of Gunnar Andersson (110) in part confirm Blytt's sequence, but as regards the latter part of the postglacial period his conclusions are very different. He finds that the melting of the ice began in a high arctic climate, the Mollusca of the *Yoldia* sea, which is its equivalent, indicating a mean annual temperature of —8° to —9° C., but the conditions rapidly improved, the mean temperature at the beginning of the *Ancylus* period being at least 2° C. The early *Ancylus* period was marked by a forest of pines, which as the

temperature continued to rise were joined by oak, Norway maple, and especially hazel. Southern plants reached their maximum northern distribution, and Andersson has plotted this on maps in the case of the hazel and the water Caltrop (*Trapa natans*). The summer and autumn temperatures during this period were about 2½° C. above the present, but the ivy, which is limited by the winter isotherm of −3½° C., extended no farther north than at present, indicating that there was no appreciable change in the winter temperatures.

Andersson finds that the passage from the *Ancylus* lake to the *Litorina* sea took place at about the maximum of temperature, but very soon afterwards the climate began to deteriorate, and as a result of the examination of the moraines of recent glaciers formed during the last centuries, Andersson concluded that a slow secular deterioration of temperature is probably still taking place. He thus finds the warm period to end at an earlier period than does Sernander. Further, he will not admit the alternation of wet and dry periods postulated by Blytt and Sernander. The result of the *Litorina* subsidence was to convert the warm, dry period into a warm, wet period; as the land rose again the climate gradually became colder and drier until it reached its present conditions. The flora associated with the *Litorina* subsidence suggests an annual precipitation in south Sweden of about 1,000 millimeters. The tree stools of Blytt's "subboreal" layer Andersson considers to occur at all levels in the peat, and to be really the result of the bog rising above its water table.

Sernander supports his conclusions by reference to stools in lake basins, and to calcareous tufa deposits. Gavelin (111) studied the changes of level in Lakes Vanstern and Kalfven in Smaland, and found that there were two periods, which he attributes to the boreal and subboreal periods, during which the climate was so dry that trees were able to grow below the level of the outlet of the lakes, so that they must have been without outlet during the greater part of the year. The calcareous tufa of Skultorp in Vastergotland, studied by Hulth (112) bears this out, for intercalated in the tufa are two mold beds during which it ceased to form and soil accumulated on its surface.

Altogether, the evidence seems to favor Sernander's interpretation far more than Andersson's.

In Norway the sequence of events has been described by J. Holmboe and P. A. Øyen (113). In marine terraces of the maximum late glacial depression, associated with recession moraines on the Norwegian coast, Rekstad (114), Øyen, and Kolderup have found arctic plants, especially *Salix polaris*. As the land rose the climate became markedly milder, and in a marine bed underlying a peat bog 145 meters above sea level have been found *Betula odorata* and *Juni-*

per communis. The rise of temperature still continued, reaching a maximum more than 2° above the present, when the upper limit of the fir in south Norway was 350 to 400 meters higher than now, and at Folgefonn, in 60° N., as much as 550 meters, and all the coastal islands, now barren, were clothed with forests as far as Ingo Island at North Cape. From this point the climate deteriorated.

In the peat bogs of Norway, Øyen also found evidence for a succession of wet and dry periods. The *Tapes* period (the equivalent of the *Litorina* period) had a warm, humid climate with a small annual range; this was the beginning of the neolithic period in Norway. The peat of this period is overlain by a layer of tree stools representing a drier climate, which at first was warmer than the present, forming the neoboreal period, but afterwards became cooler, forming the subboreal period. This in turn was followed by a renewed formation of peat due to a period of greater rainfall, the sub-Atlantic period, the subboreal and sub-Atlantic corresponding to the *Ostrea* stage. The present period is characterized by a somewhat drier climate, for trees are now growing upon the peat in many places.

In the deposits of the *Mactra* stage, preceding the *Tapes* period, Øyen found plants requiring a drier and warmer climate than that of to-day, but the marine Mollusca indicate a relatively low temperature of the sea, so that there was probably a continental type of climate with warm, dry summers and severe winters. This is borne out by the fact that terraces of erosion were far more marked than terraces of deposition during this period. Conditions in Denmark were fairly similar to those in Scandinavia, except that trees occur more frequently in the peat bogs, and there is no distinct dry period corresponding to the boreal of Sweden. The succession made out by Nordmann (114a) is as follows:

Tree period.	Baltic period.	Climate.	Land and fresh-water Mollusca.
Beech (fir dies out).	*Mya arenaria.*	Temperate island climate (July, 16° C.).	
Oak (beech scarce).	Younger *Tapes* (*Dosinia* beds).	Island climate (July, 16–17° C.).	
	Older *Tapes* (greatest sinking).	Island climate (July, 17° C.).	*Planorbis corneus.*
Fir (oak begins to come in).	*Ancylus.*	Dry mainland climate, cold at first but ameliorating and warm at end.	*Bithynia tentaculata. Planorbis Stroemi.*
Aspen.			*Valvata cristata. Planorbis Stroemi.*
Younger *Dryas.*	Arctic.	*Zirphaea* beds.	Arctic.

The replacement of the oak by the beech was due rather to a decrease in the summer warmth than to a change in the humidity; this decrease in temperature appears to be still in progress, for the beech, though thriving in the south of the country, has difficulty in maintaining its ground in the north.

Regarding the postglacial period in north Germany, a great amount of evidence was presented at the International Geological Congress at Stockholm in 1910 by Herren Schulz, Krause, Ramann, Weber, Stoller, Graebner, Menzel, and Wahnschaffe (115). The views of these authors are very conflicting. The prevailing note is one of caution in the handling of peat bog sections, as there is a natural sequence of events in the growth of a bog, quite apart from climatic changes. The normal section of a north German bog according to C. A. Weber is:

1. Glacial floor.
2. Lacustrine deposits.
3. Sedge peat. Telmatic.
4. Brushwood peat (*Alnetum*). Semiterrestrial.
5. Fir and birch wood peat above generally a layer of fir stools, below one or two stool layers. Terrestrial.
6. Older *Sphagnum* peat. Semiterrestrial.
7. "Grenzhorizont," a hardened surface with heath peat. Terrestrial.
8. Younger *Sphagnum* peat. Semiterrestrial.

In the first six of these beds he finds nothing which is not the direct result of the growth of the peat bog, but the layer of heath peat, No. 7, can not be so explained; it certainly indicates a very marked and long dry period intercalated between two wet periods. The "Grenztorf" is a widespread horizon, which according to Weber falls at the end of the neolithic, long after the *Litorina* period. Ramann, however, considered that even the Grenztorf is a consequence of the *Sphagnum* peat outgrowing its water supply.

J. Stoller, as a result of studies of pollen grains in the peat bogs, also regards the Grentztorf as representing a dry period, during which the oak predominated, but he places it at the end of the *Ancylus* and the beginning of *Litorina* time. The melting time of the ice was dry and fairly cold, the remainder of postglacial time was moist. Gradmann also assumed two dry periods, one late glacial, and the other in the neolithic period. The latter was marked by the Grenztorf, loess younger than Penck's Daunstadium (see Switzerland) and steppe mammals, especially large numbers of wild horses. The researches of Schulz on the origin and present distribution of the plants of north Germany also point in the same direction, and suggest that at one period the summers were warmer than and the winters as warm as the present.

Probably the most valuable of the contributions was that by H. Menzel, dealing with the land and fresh-water Mollusca. He

divides the occurrences into a number of zones, which, with their climatic values and their probable equivalents in the sequence of floras and in the Baltic periods, he tabulates as follows:

Land and fresh-water molluscan zones.	Climate.	Floral periods.	Baltic periods.
Dreissensia polymorpha and *Helix pomatia*.	Temperate (dry).	Beech period.	*Mya* period.
Planorbis corneus and *Paludina vivipara*.	Temperate (somewhat damper).		
Planorbis umbilicatus and *Bithynia tentaculata*.	Temperate. Perhaps warmer and drier at the beginning (continental).	Oak and lime period.	*Litorina* period.
Planorbis Stroemii.	Subarctic.	Pine and birch.	*Ancylus* period.
Arctic Mollusca.	Arctic.	*Dryas*.	*Yoldia* period.

Reference must be made also to a paper by R. Stahl (116) in 1913, in which fluctuations of water level in lakes and rivers, attributed by him to the rising and falling of the Baltic, were demonstrated on archeological grounds. Neolithic dwellings of the beginning of the *Litorina* period in Lake Drewitzer were submerged later to a depth of 5 to 6 meters. In the "Wendian" period the water again sank so low that the island of Wend was habitable. He places the Grenztorf at the beginning of the *Litorina* period.

In the face of this diversity of opinion it is difficult to frame a working idea of the course of events, but a few points may be mentioned. In the first place, it seems fairly certain that since glacial times there have been two dry periods in north Germany. The first of these occurred soon after the retreat of the ice from the German coast, and probably while it still occupied part of the Baltic. East and northeast winds acting on the materials left behind, built up dunes concave toward the west, which have subsequently had their slope but not their shape modified by west winds, as described by Solger and Svastos (117). The climate was still subarctic, but as elevation had already commenced in north Germany this stage is often attributed to the *Ancylus* period, though it corresponds in phase only and not in time to the *Ancylus* period of Scandinavia. When the elevation extended into Scandinavia and the Baltic became the fresh-water *Ancylus* lake, the ice was retreating rapidly under a climate which was by no means subarctic, but which was distinctly dry and continental.

Thus the beginning of the *Ancylus* period in Scandinavia was marked by a dry climate probably due both to elevation and to the

vestiges of the ice sheet, but in Germany, where elevation was less and the ice was more remote, the traces of the continuation of the dry period into the period of higher temperatures are slight. Probably also, in the course of development of modern storm tracks, North Germany became more humid earlier than Scandinavia.

The "Grenztorf" is separated from this earlier dry period by a considerable interval, during which *Sphagnum* peat accumulated. This *Sphagnum* peat falls naturally into place in the period of the *Litorina* depression, and the "Grenztorf" would then be associated with the elevation which terminated that period. Its occurrence finds an obvious explanation in the high temperatures which prevailed at that time over Scandinavia, allowing the cyclonic storms to take a more northerly course, so that north Germany largely escaped them. The "Grenztorf" then corresponds to the boreal period of Sweden, a correlation which is confirmed by the fact that each of them is associated with predominant forests of oak.

At the International Congress at Stockholm short accounts were given also by Kupfer and Lindberg of investigations in the Baltic Provinces of Russia and in Finland. Kupfer found that the cold climate of the last glaciation was followed first by a subarctic climate and then by a dry climate resembling that of central Russia. This, which evidently corresponds to the *Ancylus* elevation, gave place during the *Litorina* subsidence to a damp, warm period which brought the climate and vegetation of the western European coasts to the eastern Baltic. Kupfer makes no mention of a second dry period between this and the present day, but such a dry period is suggested by the reference made by G. I. Tanfiljew at the same congress, to layers of tree stools in the peat, and to the gradual replacement still continuing of forests by steppe in central Russia, though Tanfiljew did not attribute these phenomena to climatic changes.

The most important result of the work of H. Lindberg was the discovery of a well-marked warm period in Finland, characterized by the occurrence of a horizon with *Trapa natans*, *Carex pseudocyperus*, and *Ceratophyllum demersum*. *Trapa* is now entirely extinct in Finland; the other two are found in peat beds far to the north of their present habitat. This warm period coincided with the latest *Ancylus* period and the maximum extent of the *Litorina* Sea, for at Sakkola in the Carelian Isthmus (and in the island of Aland in the Gulf of Bothnia, as recorded by P. H. Olsson in 1900) the *Trapa* bearing deposits are directly overlain by beaches of the *Litoria* Sea.

Briefly summing up, we find that in postglacial times in northern Europe there have been two dry periods, one preceding and the other following the Litorina subsidence, and that in the Fennoscandian region these two dry periods were also warm.

9. THE ALPS.

Having now dealt with the whole area covered by the north European system of ice sheets, I can return to central Europe, and refer to the glaciation of the Alps. Here one great work—Penck and Brückner's "Die Alpen in Eiszeitalter" (117*a*)—entirely dominates the literature. The authors adopt a fourfold glaciation, with retreat stadia since the last glaciation, the complete scheme being as follows:

Pliocene.	Duration about—
Gap.—Elevation of 500 to 600 meters on the southern margin of the Alps.	
Guenz glaciation.—Our knowledge of this is slight, but the snow line probably lay 1,200 meters lower than now. Upper Dekkenschotter of Rhine Valley.	
Guenz-Mindel interglacial.—Nothing is known with certainty. From the relations of the gravels of the Guenz with those of the Mindel glaciation, its duration was probably similar to that of the Riss-Wurm interglacial.	? 60,000 years.
Mindel glaciation.—The maximum glaciation over the northeast, east and southeast of the Alps. Snowline about 1,300 meters below the present. Lower Dekkenschotter of Rhine Valley.	
Mindel-Riss interglacial.—Very long in duration; a great amount of erosion and weathering was effected. At Leffe peat with *Elephas antiquus* and *Elephas meridionalis* is referred to this. Chellean. Elevation occurred during this interglacial.	240,000 years.
Riss glaciation.—Maximum glaciation in the Rhine Valley, France, Switzerland and the Po Valley. Snowline about 1,200 meters below present. Early Mousterian. High terrace of Rhine Valley.	
Riss-Wurm interglacial.—Relatively short amount of erosion and weathering indicates a duration only one-fourth as great as that of the Mindel-Riss interglacial. Warmer than the present. Flora of Hötting breccia indicates a temperature 2° higher. Fauna includes *Elephas antiquus* and *Rhinoceros Merckii*. Late Mousterian. Most of the loess dates from the conclusion of this interglacial.	60,000 years.
Wurm glaciation.—Less in extent than the Riss glaciation. The snow line lay about 1,200 meters lower than at present. Fauna and flora arctic. In the middle of the Wurm glaciation was an interstadial period, the *Achen interstadial*.—Solutrean, and at its close, early Magdalenian. Low terrace of Rhine Valley. Next occurred a retreat of ice, followed by a slight re-advance, the *Buhlstadium*, snow line 900 meters lower than now. Magdalenian.	Post-Wurm period, 20,000 years. Post-Buhl period, 16,000 years.
Followed by—	
Gschnitz Stadium.—Snow line 600 meters lower. *Daun Stadium*—Snow line 300 meters lower. Middle neolithic.	Post-Daun period, 7,000 years.

The authors have no data for the duration of the glacial periods, but assume arbitrarily that the duration of the Wurm glaciation was equal to that of the Riss-Wurm interglacial, or 60,000 years. This appears to me far too long, for on their own showing the retreat stadia can not have lasted more than about 4,000 years each, yet these sufficed to accumulate well-marked end moraines, and in Sweden, De Geer has shown that a few centuries sufficed to form the great end moraines of that country.

In the southeast corner of the Alps the depression of the snow line was much less than elsewhere, being only about 800 meters both in the Wurm and Riss periods. This deviation the authors attribute to the fact that owing to elevation the Adriatic, from which this region draws its supply of moisture, lay at a much greater distance than it does now so that the rainfall was less. Elsewhere the amount of rainfall appears to have been similar to the present, westerly winds still being the chief rain bearers, and the glacial periods were caused by falls of temperature, not by increases of rainfall. This is further borne out by the changes in the fauna and flora.

A few remarks may be made about the contributions of other authors to the discussion of Alpine glaciation. R. Lepsius (118) is the only author in recent years who has disputed the fourfold glaciation of the Alps. A paper at the International Geological Congress at Stockholm in 1910 explaining all the Alpine phenomena as due to a single glaciation was badly received and its very apparent weaknesses pointed out by most of those who took part in the discussion. The modest values attributed to their interstadial periods by Penck and Brückner have been emphasized by various authors. A. Schulz (119) considers on botanical grounds that the interstadia between the Buhl, Gschnitz, and Daun stadia were warm and dry; A. von Hayek (120) postulates one warm-dry period only which he puts in the Gschnitz-Daun stadium. A. Gutzwiller (121) finds that at Basle the younger loess overlies the lower terrace and was formed in the pre-Buhl interstadium. J. Hug (122) has shown that at Zürich the Rhine during the Mindel-Riss interglacial cut down 10 to 30 meters below its present bed; and afterwards filled its valley with high terrace gravel. The Rhine erosion during this interglacial is estimated at 210 meters. Further, between Basle and Schaffhausen the lower terrace of the Rhine is divided into two parts, at 30 meters and 18 meters above the river; the former passes into the outer glacial wall, so that the latter must correspond to the retreat moraines.

A serious criticism of the views of Penck and Brückner is made by H. Obermaier (123), who entirely rejects Penck and Brückner's correlation of the archeological and geological stages, putting the Chellean in the Riss-Wurm interglacial instead of in the Mindel-Riss, the Mousterian in the Wurm glacial period, and the Aurignacian and Solutrean post-Wurm. This paper does not seem to have much value in itself, since it is supported largely by the ingenious manipulation of Penck's own data, but it represents the views of a number of French geologists. Its proof or disproof largely hangs on the correlation of the Alpine glaciations with those in other countries.

CORRELATION.

Direct correlation with the north German plain is difficult and can only be made on general grounds. In his chronological studies in Sweden, De Geer found that the retreating ice reached the south of Scania about 12,000 years ago, and he allowed another 5,000 years for the recession across the Baltic, making the maximum of the Baltic readvance 17,000 years ago; this agrees very well with Penck and Brückner's datum of 16,000 years for the age of the Bühlstadium. Working backward from this, we have—

NORTH GERMANY.	ALPS.
Baltic readvance.	Bühlstadium.
Baltic interstadial.	First interstadial.
Third glaciation.	Würm glaciation.
Interglacial with *P. Duboisiana*.	Riss-Würm interglacial.
Second glaciation.	Riss glaciation.
Interglacial with *P. diluviana*.	Mindel-Riss interglacial.
First glaciation.	Mindel glaciation.
	Günz-Mindel interglacial.
	Günz glaciation.

The interglacial with *P. diluviana* in Germany and the Mindel-Riss interglacial in Switzerland were both long periods with considerable tectonic disturbance.

Correlation with Holland and the lower Rhine can be made by means of the Rhine terraces. In the upper Rhine, at say Basel, we have the upper Dekkenschotter, lower Dekkenschotter, high terrace, and low terrace, corresponding to the first, second, third, and fourth glaciations. As has been described in the section on Holland, when these are traced downstream they converge, the lower Dekkenschotter become the chief terrace and overlie the continuation of the upper Dekkenschotter, separated from them by finer deposits and by the equivalents of the Tegelen clays. The high terrace becomes the series grouped together as high and middle terraces, and the low terrace remains unchanged. I have already correlated the chief terrace with the maximum glaciation of Holland and this with the first glaciation of north Germany, and the high and middle terraces with the second glaciation of Holland and Germany, so that the three districts form a triangle in which all the correlations agree. These fit in better with the archeological views of Gagel and Penck than with those of Schmidt and Obermaier, but this point must be left till later.

10. FRANCE.

The Alps extend into France, but nothing need be added to the section dealing with the glaciation of that mountain group as worked out by Messrs. Penck and Brückner. In addition to this there were

local centers of glaciation in the Vosges, the Plateau Central, and the Pyrenees, but the most important Quaternary deposits of France are the famous river terraces with their paleolithic implements.

The Vosges extend into Alsace, where they have been studied by E. Schumacher and W. Dames (124), who distinguished three sets of gravels, a mass on the plateau, the Dekkenschotter, which can not be split up into stages, and also two marked terraces in the valleys. The older of these was dissected into more or less isolated portions before the formation of the younger; it ends upstream in accumulations of blocks and patches of bowlder clay, while the younger terrace ends upstream in well-marked moraines.

The glacial stages of the French high Vosges were also investigated by A. Lepplt (125) and correlated by him with the terraces of the Moselle Valley and thus with those of the Rhine Valley. He finds evidence of four glaciations:

1. An ice sheet covering the west and south Vosges before the formation of the valleys.

2. A glaciation which filled the valleys of the Vosges when these were still only slightly eroded.

3. Great Moselle Glacier of the low valleys with its end moraines at Eloyes and near Noir Gueux.

4. Younger glaciation in the sources of the Moselle, Moslotte, Vologne, and Cleurie, of less extent than the preceding and its end moraines inclosing lakes.

The first two of these correspond to the upper terrace group of the Moselle, of which the lowest stage is the chief terrace, confluent with that of the Rhine. No. 2 is therefore identical with the first glaciation of North Germany and the Mindelian glaciation of the Alps, and No. 1 may represent the Gunzian glaciation. No. 3 gives rise to the middle terrace group of the Moselle, 30 to 100 meters above its bed, the lowest stage of which is the high terrace, confluent with the high terrace of the Rhine and therefore representing the second glaciation of Germany and the Rissian of the Alps. No. 4 gives rise to the low terrace group of the Moselle, 8 to 30 meters above its present bed, and must represent the Wurm glaciation.

The formations of the Plateau Central were described in detail by E. Haug (125); they contain very rich mammalian faunas. The oldest Quaternary deposits are the Pumiceous conglomerates of Perrier near Issoire (Pûy-de-Dome) and the mastodon sands of Pûy. They were attributed by M. Boule to the mid Pliocene, but Depéret has shown that the fauna is strictly Quaternary, including besides *Mastodon*, *Elephas meridionalis*, *Equus*, and *Bos*. At Perrier the beds have filled a valley cut deep in an upper Neocene basaltic flow, they consist of alternations of gravels and quartzose sands, with large blocks, often forming a conglomerate. The blocks are derived from

all the Neocene beds of Mount Doré; they are angular and sometimes striated and polished. A. Michel-Lévy considered the formation to be glacial, but it is not a true moraine. M. Boule considered it to be a volcanic agglomerate, but Haug believes it to be similar to the palagonite formations of Iceland formed during the melting of glaciers by volcanic eruptions. The mammalian fauna closely resembles that of the Val d'Arno in Italy—*Ursus arvernensis*, *Machaerodus crenatidens*, *Hipparion* sp., *Equus stenonis*, *Tapirus arvernensis*, *Rhinocerus etruscus*, *Bos elatus*, *Mastodon arvernensis*, *Elephas primigenius* (?). The horizon seems to be Gunzian.

To the same horizon belong the *Mastodon* sands of le Velay, in the Loire Valley, formed when the river lay much above its present level. These consist of 100 meters of sands, with cold diatoms and temperate higher plants. The sands contain several basaltic flows and agglomerates. The fauna is similar to that of Perrier, but includes also *Rhinoceros leptorhinus*, *Hyaena*, and *Mastodon borsoni*, while A. Laurent and Broquin found at Crozas (Haute Loire) associated with the two species of *Mastodon*, a molar of *Elephas primigenius*.

In the Perrier Valley this formation is overlain by the "subbasaltic alluvium" of Cantal and Velay. Near Pûy M. Boule found in a fine gray bed overlying the coarser *Mastodon* sands *Machaerodus nainzellei*, *Hyaena brevirostris*, *Equus stenonis*, *Rhinoceros etruscus*, *Hippopotamus major*, *Cervus pardinensis*, *Bos elatus*, and *Elephas meridionalis*. The presence of *Hippopotamus* indicates a temperate climate, but the fauna shows the beds to be still early Quaternary, so that the "subbasaltic alluvium" must fall in the Gunz-Mindel interglacial.

These alluvial deposits are overlain by immense flows of plateau basalt, in which the later Quaternary valleys are deeply cut. On this sheet of basalt in the Cantal rest the oldest undoubted glacial remains, those of the "plateau glacial" of M. Boule. It is very well developed in Cantal and on Mount Doré, but there is no trace of it in Velay. The plateaus are covered by thousands of small roches moutonnées often striated, and with erratics on the lee side. No moraines have been found, but to the west, near Bort, are fluvio-glacial terraces 200 meters above the Dordogne.

In this old glacial level, the valleys of the Dordogne, the Cere, and all the great valleys of the Plateau Central, were cut during the following interglacial. In river deposits in these valleys in the Auvergne are remains of *Arvicola* sp., *Equus caballus*, *Rh. Mercki*, *Hippopotamus amphibius*, *Cervus elaphus*, *C. intermedius*, *C. solihacus*, *Megaceros*, *Bison priscus* and *Elephas cf. meridionalis*. In the valleys of the Jordanne and the Cere, in the Cantal, P. Marty and M. Boule have described very fresh lateral and frontal moraines

which downstream pass into the low terrace, 20 meters above the present level. The high terrace in these valleys is 40 meters above the present level and indicates an older glacial extension, for it contains very big blocks, sometimes little rolled, but the moraines corresponding to this glaciation are still unknown or have not yet been distinguished from those of the last glaciation. The lower terrace near Sarliève contains *Elephas primigenius*, *Rhinoceros tichorhinus*, *Rangifer tarandus* and late paleolithic implements, and must accordingly represent the Wurm glaciation, so that the higher terrace corresponds to the Riss glaciation, and the glacial remains of the plateau to the Mindelian. This correlation is further borne out by the succession in the valleys of Aquitania and in the Pyrenees. The glacial phenomena here were investigated by A. Penck in 1885 (126). The moraines almost everywhere rest on ancient rocks, and he was unable to find two superposed moraines separated by temperate deposits, but there is a clear distinction between exterior and interior series of moraines, the latter being the younger. The snow line was about 1,000 meters below the present; there was also a late glacial stadium indicated by a chain of valley lakes with the snow line 600 meters below the present. He distinguished three well-marked developed gravel terraces, especially thick in the Toulouse region; they contain striated pebbles, and the two older are weathered much more than the younger. These terraces were investigated in more detail, especially in the valley of the Garonne by M. Boule (127) who showed the existence of four terraces, at about 130, 100, 55, and 15 meters above the present valley. The two oldest of these are very much weathered, the granite pebbles being entirely decomposed; they can not be connected with any moraines. The third or "high terrace," 55 meters is formed by pebbles much less weathered than those of the 100-meter terrace, but the granites and schists are somewhat altered; this terrace apparently corresponds to older moraines in the Pyrenees. The third terrace contains quartzite implements of Acheulian type. The low terrace (15 meters) is composed of very fresh pebbles together with weathered ones from the high terraces; upstream it passes into a very fresh moraine. These moraines and the two lower terraces can be distinguished in most of the Pyrenean Valleys.

Summary for the south of France and the Plateau Central:

Gunzian:	(?) Pumiceous conglomerate of Perrier (Püy-de-Dome).
	Mastodon sands of Velay.
	130-meter terrace of Garonne.
Gunz-Mindel:	Subbasaltic alluvium of Perrier (*Machaerodus*; *Elephas meridionalis*).
Mindelian:	"Plateau glacial" of Plateau Central.
	200-meter (fluvio-glacial) terrace of Dordogne.
	100-meter terrace of Garonne.

Mindel-Riss:	Erosion in Dordogne and Garonne.
	Beds with *Hippopotamus* and *Rhinoceros Merckii* of Dordogne.
Rissian:	"High terrace" (40 meters) of Dordogne, with big blocks.
	55-meter terrace of Garonne, with older moraines. Acheulian.
Wurmian:	"Low terrace" (20 meters) of Dordogne, passing into very fresh moraines.
	15-meter terrace of Garonne, with younger moraines.

PARIS BASIN.

In the north of France we have the Paris Basin, which is important because of its famous paleolithic sites. The sequence has been frequently studied, the results being summarized by J. Ladrière (128) in 1890–91 and more recently by E. Haug in 1912 (125). The oldest Quaternary deposit of the district appears to be a bed of course sand and fine gravel at St. Prest, near Chartres, containing *Trogontherium Cuvieri*, *Equus Stenonis*, *Rhinoceros* sp., *Hippopotamus major*, *Cervus carnutorum* and *Elephas meridionalis* associated with eoliths. *Hippopotamus* shows this to be a temperate fauna, and from its ancient facies, in spite of the absence of *Machaerodus*, it must be referred to the same horizon as the subbasaltic alluvium of Perrier, i. e., the Gunz-Mindel interglacial of the Alps.

In the Paris Basin are three gravel formations, the "plateau gravels," the "high terrace," and the "low terrace," at Paris these two terraces occur on the slopes below the plateau gravels at heights of 30 meters and 5 meters above the level of the Seine; downstream the high terrace comes to rest on the plateau gravels, in which case they are separated, not by a fine interglacial series, but merely by a bed of course, gravelly sand. The two deposits must not be separated, but must be treated together, like the 130-foot and 100-foot terraces of the Thames east of London. The plateau gravels rest on the mammaliferous sand of St. Prest, while stratigraphically they evidently correspond with part at least of the upper terrace group of the Moselle. The pebbles composing them are very much altered, and they contain some big blocks of granite. The plateau gravels contain in addition remains of *Elephas primigenius* and *Rhinoceros tichorhinus*, and in the Seine Valley, also *E. antiquus* and *Rh. Merckii*.

On the gravels of the "high terrace" often rests a thick series of finer sediments—sands, fine gravels, and clays—and a similar series often underlies the gravels of the low terrace. These beds contain an interglacial fauna including *Hippopotamus major*, *Rhinoceros Merckii*, and *Elephas antiquus*. This warm fauna is associated with implements of Chellean type.

The succeeding gravels of the "low terrace" contain a well-marked cold fauna—*Elephas primigenius*, *Rhinoceros tichorhinus*, and *Cer-*

vus tarandus, associated with Mousterian implements. The division between this bed and the preceding beds with the warm fauna is very marked, e. g., at Chelles itself, cemented sands and gravels some meters above the level of the Marne containing *E. antiquus* and Chellean implements are overlain with an eroded junction by loose pebbles of the low terrace with *E. primigenius* and Mousterian implements.

To the interglacial between the high and low terraces must be attributed the tufa beds, 15 meters thick, on the banks of the Seine at Celle-sous-Moret, resting on alluvium with *Elephas antiquus*. The lower and middle part of the tufa bed contains besides willow, birch, poplar, etc., leaves of *Laurus nobilis*, *Ficus carica*, *Cercis siliquastrum* (judea tree) and *Buxus sempervirens*, indicating a climate milder than the present: this part contains Chellean implements. The upper part of the tufa contains only local plants, with Acheulian implements; it is overlain not by gravels of the low terrace, but by the loess-loam which overlies these gravels.

Final confirmation of the correlation of the high and low terraces of the Seine with the first and second glaciations of north Germany is given by the Mollusca, for at Cergy near Pontoise, in sands and gravels with *Elephas antiquus* and Chellean implements, occurs a fauna including *Corbicula fluminalis*, *Belgrandia gibba*, and *Bithynia tentaculata*, while *fluminalis* has also been found near Abbeville associated with Chellean implements and the typical Chelles fauna.

The later stages of the glacial period in the Paris Basin are known only from the cave deposits of the Cure and Yonne Valleys (129). These contain three archeological horizons, separated in two of the caves by flood loams of the Cure. The lowest horizon contains Acheulian and Mousterian implements with remains of *Elephas primigenius*, *Bison*, *Cervus tarandus*, *C. elephas*, *Rhinoceros*, *Felis spelaea*, *Hyaena spelaea*, *Hippopotamus major*, *Equus*, and rodents. This is a mixed fauna, and since Acheulian implements are associated with cold forms, and Mousterian first with cold and later with warm forms, it is evident that this horizon represents the low terrace of the Seine and a succeeding mild interval.

The middle horizon contains Aurignacian implements associated with the same fauna except *Hippopotamus* and *Felis*, and in addition contains the polar fox, ibex, chamois, and elk. The Solutrean industry is imperfectly developed, and the upper horizon contains chiefly Magdalenian implements associated with *Cervus tarandus*, *Equus caballus*, and *Bison*. The last two beds therefore indicate a return of cold conditions, which must be the equivalent of the third glacial of north Germany and the Wurmian of the Alps.

SOMME VALLEY.

V. Commont (130) gives the following general succession:

At Amiens there are four principal zones of river gravels, separated by slopes of chalk.

1. Terrace of 10 meters (altitude 23 to 29 meters: bed of Somme + 13 meters; low terrace.
2. Terrace of 30 meters(altitude 40 to 45 meters, St. Acheul).
3. Terrace of 40 meters, divisible into two beds.
4. Terrace of 55 meters, which occupies the summit of the plateau.

All these terraces are inclined downstream, their altitude above the present bed of the Somme diminishing as they approach the sea, and at Abbeville the second terrace reaches the present level of the Somme. Gravels of the third terrace have furnished a flora of Pliocene affinities at Abbeville, and remains of a coarse "pre-Chellean" industry at Amiens. The true Chellean characterizes the 30-meter terrace, and "evolved Chellean" the 10-meter terrace, with *Elephas antiquus* and *Hippopotamus.* At the end of Chellean time, owing to a relative subsidence of the land, the sea invaded the Somme Valley up to Menchecourt, depositing calcareous sands with *Corbicula fluminalis*, etc., overlying the gravel at a height of about 6 meters above present sea level. At the same time on the flanks of the valley were forming the pebble beds and *limon moyen* (old loess) with Acheulian implements.

A fresh lowering of base level enabled the river to cut its bed deeper not only in the Chellean gravels of the low terrace but also in the underlying chalk. The gravels deposited at this stage contain *Elephas primigenius*, *Rhinoceros tichorhinus*, and *Cervus tarandus*, with Mousterian implements. From this period date also the deposits of tufa and older peat of Longpré and Montières, while on the slopes was forming the "ergeron" (younger loess) with Mousterian and Aurignacian industries. A dry, cold period followed this moist period—the epoch of the formation of the Solutrean and Magdalenian brick earth by alteration of the Ergeron. This period was followed by renewed subsidence, permitting the filling up of the river valley by loam, tufa, and peat. This peat commenced with a formation of alder, hazel, oak, and walnut, the remains of which are now below sea level, and extend to the coast, where they occur on the shore below sea level, and evidently correspond to the submerged forests of the opposite coast of England.

'The average thickness of the peat formation at Abbeville is nearly 10 meters and M. Boucher de Perthes found in it at a depth of 40 centimeters several large, flat dishes of Roman pottery, which were at least 14 centuries old. If this rate of 3 centimeters per century had not been exceeded—and the earlier peat is naturally more com-

pressed than the latter—it gives a period of nearly 30,000 years since the beginning of accumulation of the peat.

The correlation of the terraces in the neighboring valleys of the Seine and the Somme is obvious, the extension of the Thames Valley fairly so:

	Seine Valley.	Somme Valley.	Thames Valley.
1	Plateau gravels.	Terrace of 40 meters.	130-foot terrace.
2	High terrace (30 meters).	Terrace of 30 meters.	100-foot terrace.
3	Low terrace.	Terrace of 10 meters.	50-foot terrace.
4	Loess-loam.	Marine sands and loess.	"Warp and trail."

The agreement of the levels is perfect, and also stage No. 2, and the interval between 2 and 3 is characterized throughout by the occurrence of the warm Chelles fauna and implements of older paleolithic (Chellean-Acheulian) types.

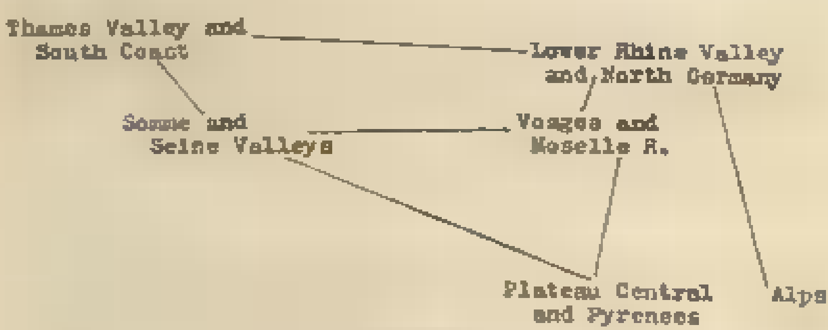

Fig. 2.

The loess-loam and underlying marine sands of Menchecourt are found again on the coast in the raised beach and overlying deposits. The classic section is that of Sangatte near Calais described by Prestwich. The raised beach lies about 10 feet above the level of the present beach, and is directly overlain by typical "head" in which are intercalated occasional bands of loess containing the land shells characteristic of that formation. Similar sections occur at several points on the northeast coast of France, and there is no doubt that they agree with the exactly parallel sections at Brighton, on the coast opposite, thus confirming our inferences about that deposit and the age of the "head."

France thus forms a triangle in which the Quaternary deposits at each corner can be directly correlated with those of the neighboring parts of Europe.

Thames Valley and southern coast.	Somme and Seine Valleys.	Vosges and Moselle.	Lower Rhine Valley.	Plateau Central, etc.	Alps.
		? District ice sheet of Vosges and upper terrace.	(? Joint delta of Rhine and Meuse.	Pumiceous conglomerate of Perrier. 120-meter terrace of Garonne.	Günzian.
			Tegelen clays.	Subbasaltic alluvium of Perrier.	Günz-Mindel.
Chalky boulder clay. Raised beach of Chichester and west. 100-foot terrace.	Plateau gravels and 40-meter terrace.	Shallow valley glacier and chief terrace.	Groundmoraine of first glaciation. Chief terrace.	"Plateau glacial." 55-meter terrace (Dordogne). 100-meter terrace (Garonne).	Mindel.
Interglacial beds of Selsey. 100-foot terrace and part of 50-foot.	30-meter terrace and part of 10-meter terrace.		(Eem horizon.)	Beds with *Hippopotamus* in Dordogne.	Mindel-Riss.
"Warp and trail." Raised beach of Brighton. "Head."	Marine sands and loess loam.	Great Moselle glacier and middle terraces of Moselle.	Moraine of second glaciation (not reaching Rhine). Middle terrace.	High terrace (40-meter) of Dordogne. 35-meter terrace and moraines.	Riss.
	Old peat of Somme.				Riss-Würm.
? Low terrace.	Upper loess-loam.	Small Moselle glacier and low terrace.	Low terrace.	Low terrace of Dordogne and Garonne, with moraines.	Würm.

I have already worked out the correlation between the east coast of England and Thames Valley on the one hand and Holland and north Germany on the other, and also between the latter and the Alps. All these correlations, which are based on a variety of geological evidence, mainly paleontological and stratigraphical in its nature, agree, giving very strong support to the classification adopted.

CONCLUSION.

The series of cross correlations described in the preceding pages show definitely that glacial and interglacial periods were not the local phenomena that they are sometimes considered to be, but were

well-marked events which occurred simultaneously over at least the whole of northern Europe. The proof that the simultaneity extended also to the glacial periods of other continents is naturally more difficult, since direct correlation is mostly out of the question. A great deal of evidence on the subject, based chiefly on the amount of weathering undergone, has been brought forward by F. Leverett (131). After personally examining a great number of exposures in America and the most typical ones in Europe, he was convinced that the four great periods into which the American glacial deposits fall show such remarkable resemblances with the periods in Europe, both in the amount of weathering undergone and in the intervals between the glaciations, that the two series must be directly comparable. These stages are:

American.[1]		European.	
Keewatin.	Labrador.	North European.	Alps.
Wisconsin.	Wisconsin.	Upper diluvium.	Würm.
? Iowan.	Illinoian.	Middle diluvium.	Riss.
Illinoian.			
Kansan.	? Kansan.	Lower diluvium.	Mindel.
? Pre-Kansan.	? Jerseyan.	?	Günz.

[1] A review of the evidences of the Iowan stage of glaciation was made in 1914 and 1915 by W. C. Alden and Morris M. Leighton for the United States and Iowa Geological Surveys. As stated in their report, which is published in volume 26 of the Iowa Geological Survey, these gentlemen reached the conclusion "that there is what seems to the writers to be good evidence of the presence of a post-Kansan drift sheet in northeast Iowa and that this drift appears to be older than the Wisconsin and younger than the Illinoian drift * * * There is, therefore, warrant for the continued use of Iowan drift and Iowan stage of glaciation as major subdivisions of the Pleistocene classification." Following is the classification in use at present by the United States Geological Survey:

PLEISTOCENE SERIES.

9. Wisconsin stage of glaciation (of Chamberlin).
    8. Peorian stage of deglaciation (of Leverett).
7. Iowan stage of glaciation (of Iowa geologists).
    6. Sangamon stage of deglaciation (of Leverett).
5. Illinoian stage of glaciation (of Leverett).
    4. Yarmouth stage of deglaciation (of Leverett).
3. Kansan stage of glaciation (of Iowa geologists).
    2. Aftonian stage of deglaciation (of Chamberlin).
1. Nebraskan stage of glaciation (of Iowa geologists) (pre-Kansan of Chamberlin) (Jerseyan of eastern United States).

The evidence is entirely in favor of the exactness of the time agreement except in the case of the Illinoian, which seems somewhat older than the Riss; here he considers that the differences in the amount of weathering are accounted for by the differences in the amount of rainfall at present.

Independent evidence for this simultaneity was given recently by A. P. Coleman (132), who from the amount of erosion estimated the

duration of interglacial periods in America. His estimates, compared with those of Penck and Brückner for the Alps, give:

America.	Years.	Alps.	Years.
Postglacial	25,000	Postglacial	20,000
Aftonian	42,000	Riss-Würm	60,000

T. C. Chamberlin also, on the basis of age determination in Europe and America, concludes that the glacial epochs in the two continents were simultaneous (133).

In one case at least, moreover, we seem to have direct evidence for the continuous extension of a climatic period over a large part of the Northern Hemisphere; I refer to the postglacial climatic optimum, evidence of which has been found in Iceland, Spitzbergen, Franz-Josef Land, the White Sea, Greenland, and North America.

In Iceland, G. Bardarson (134) and H. Pjetursson (135) have found raised beaches and marine deposits in the north and northeast, indicating a submergence of about 17 meters and containing Mollusca which now live only on the south and southwest coasts, and consequently indicating a climate warmer than the present.

In Spitzbergen, Andersson (136) found a raised delta deposit with flowering plants not now living on the islands, and A. S. Jenson and P. Harder found raised beaches indicating a submergence of 10 to 25 meters and containing Mollusca (*Mytilus edulis*, *Cyprina islandica* and *Litorina litorea*) now extinct on the shores of Spitzbergen.

In Franz-Josef Land, Nansen (137) found *Mytilus edulis* in an old shore line at 10 to 20 meters, evidently of the same age.

In the White Sea and Murman Sea, N. Knipowitsch (138) found raised beaches with species of *Cardium* now extinct there.

In Greenland, A. S. Jensen (139) found in Orpigsuit Fjord a well-marked warm period with the land about 10 meters below its present position relative to the sea, and raised beaches containing *Mytilus edulis* even north of 66½° N., and as far as Sophia Sound in northeast Greenland, though its present northern limit in America is the Newfoundland Bank.

On the coast of Canada (Maritime Provinces) G. F. Matthew (140) found evidence of a period of *elevation*, immediately preceding the present epoch, when the climate resembled that of Middle New England.

In gravel terraces along the Niagara River, between the Whirlpool and Goat Island, A. P. Coleman (141) has found species of *Unio* not now living in the Canadian lakes, but in the tributaries of the Mississippi. The beds were formed during the last third of the

period of erosion of the Niagara gorge, and are therefore approximately contemporaneous with the *Litorina* beds of the Baltic.

In the United States the peat bogs contain plants and animals occurring fossil 50 to 100 miles north of their present limits (142). But here part at least of the warm period fell in a period of submergence, for at Boston, W. Shimer (143) found a fine silt with Mollusca, indicating a warmer climate, 15 feet above mean low tide. In South Carolina also G. T. Pugh (144) concluded from a discussion of the Pleistocene marine Mollusca that there had been a period of sea temperature slightly above the present.

Isolated pieces of evidence of a warm period immediately preceding the present have been found in many other parts of the globe, e. g., east Africa, east Australia, Terra del Fuego, and antarctica, but as these have not yet been connected up with the European area I will not describe them further. We have at least evidence of the existence of a series of climatic waves of long period extending over a considerable part of the Northern Hemisphere.

Before closing this study of the correlation of the Quaternary deposits of northern Europe, there are two points to which I should like to refer; one is the correlation of Penck and Brückner's Gschnitz and Daun stadia in the light of G. de Geer's "geochronological" work, and the other is the bearing of the loess on the correlation.

The estimate of postglacial time in the Alps made by Penck and Brückner chiefly on the basis of the amount of delta formation has already been referred to. This is:

Post Würm period, 20,000 years.
Post Bühl period, 16,000 years.

The "geochronological" work of G. de Geer in Scandinavia is well known; by counting the number of annual layers in lake sediments and identifying certain annual layers from one deposit to another he has been able to calculate the date at which various localities became free from ice, and finds that the receding ice edge reached the south of Scania 12,000 years ago. The recession from the north coast of Germany to the south of Scania can not be calculated in this way, but from a comparison of the amount of melting he estimates about 5,000 years for this period, making a total of 17,000 years since the conclusion of the Baltic oscillation. From these studies there is little doubt that the Baltic oscillation corresponds to the Bühl stadium.

Further, de Geer gives the age of the great Fennoscandian moraines near Stockholm as about 10,000 years. Penck and Brückner could not obtain a date for the Gschnitz stadium, but for the last of their stadia, the Daun, they calculate a date of about 7,000 years. The Gschnitz stadium, being intermediate, must be something between 9,000 years and 12,000 years in age, so that it is very probable that the Fennoscandian end moraines and the Gschnitz stadium are

equivalents. The Daun stadium may find its equivalent in a later set of end moraines.

The third method of testing the correlation of the deposits is by their relation to the loess. This deposit, believed to be aeolian, is not all of the same age; in the same section two loess beds of different ages may be separated by a weathered surface, but the "younger loess" occupies a well-marked horizon. In north Germany it rests upon the moraines of the third glaciation, but not upon those of the Baltic readvance, so that it evidently falls in the period of that readvance or in the Baltic interstadial. It was discussed and placed here by F. Wahnschaffe (145), who considered the Baltic interstadial to correspond to the Wurm-Buhl interstadial of the Alps, and also K. Olbricht (146). Outside the limits of the third glaciation of north Germany the position of the younger loess is less certain, but it contains Solutrean implements, which points to a similar and slightly earlier age.

In the valley of the Weser, there appear to be two terraces corresponding to the third glaciation of Germany, separated by a peat bed corresponding to the Baltic interstadial. This conclusion, based on stratigraphical evidence, is supported by the fact that loess occurs on the older but not on the younger terrace.

In the Alps the loess is considered by Penck and Brückner (loc. cit.) to be typically an interglacial formation, belonging to the close of interglacial conditions. Only in the Turin region are there extensive deposits of postglacial loess, in which, however, the characteristic fauna is missing. In the north they nowhere found it to rest on the Wurm moraines, but "the paleolithic implements which it contains are so closely related to those of the end of Wurm, that it can not possibly be much older than the latter." J. Hug (147) further claims to have found loess on Wurm moraines near Zurich, and near Basle, A. Gutzwiller (148) correlated the younger loess with the first retreat stadium, so that it seems probable that the younger loess falls in the interstadium Wurm-Buhl and in the Buhl stadium.

In the Rhine Valley there are younger and older loess deposits resting immediately on the gravels of the low and middle terraces, and immediately following those terraces in time. This confirms the correlation of the low terrace with the maximum of the third glaciation of Germany. In France also the loess ("limon" or "ergeron") of the Paris Basin is of different ages, and the younger rests on the low terrace system (latest gravels) and in part replaces it, confirming the correlation of these gravels with the low terrace of the Rhine, with the Wurm glaciation of the Alps and with the third glaciation of north Germany.

I have now summarized the stratigraphical evidence on which a correlation of the European deposits with each other and with

those of the British Isles must be based, and the further evidence of a more general character which throws light upon the correlations. It remains now only to consider the nomenclature to be adopted.

For the glacial periods the names of Penck and Brückner (loc. cit.) seem best adapted, for although preceded in point of time by J. Geikie's nomenclature, they are more definite and more widely employed. It is often difficult to say to which horizon Geikie's name would apply, as he included under the same term beds belonging to different stages.

For the interglacials the question is more difficult, as Penck and Brückner have given no definite names, and it seems convenient such should be found: I am therefore adopting Geikie's interglacial names applied to the equivalents of the British stages which he included under them, except to the well-marked Chellean interglacial. For the postglacial stages, A. Blytt's succession (149), seems too detailed and in part problematical, and the widely recognized and definite Baltic stages seem the best to adopt. The scheme for Europe accordingly becomes:

Stage.	Equivalents.
Günzian (P. & B.)	Scanian (J. Geikie). Calabrian (150) (Gignoux).
Norfolkian (J. G.)	Tegelen clays. St. Prestian (Haug). Villefranchian (Depéret).
Mindelian (P. & B.)	Saxonian (J. G.). Oldest boulder clay of Germany. Sicilian (Gignoux). Contorted drift and chalky boulder clay. Chief terrace (Rhine).
Chellean (Haug)	Helvetian (J. G.). *Paludina diluviana* beds. *Strombus* stage (Gignoux). *Corbicula* and *Cyprina* clays.
Rissian (P. & B.)	Polandian and Mecklenburgian (J. G.). Hessle stage (Wood & Harmer). Lower diluvium (Germany). Middle terrace (Rhine).
Neudeckian (J. G.)	*Paludina Duboisiana* beds.
Würmian (P. & B.)	Lower Turbarian (J. G.). Upper diluvium (Germany). Low terrace (Rhine). "Corrie" glaciers of British Isles.
Baltic interstadial	First interstadial (Alps).
Bühl stadium (P. & B.)	Baltic end moraine.
Gschnitz stadium Daun stadium (P. & B.)	Swedish end moraines.
Ancylus stage (De Geer)	Late glacial of many districts. Boreal (Blytt).
Litorina stage (De Geer)	25-foot beach of British Isles. Raised beaches of Atlantic and Arctic Oceans. Atlantic (Blytt). *Tapes* period (Brøgger).
Upper Forestian (J. G.)	Late *Litorina* and late *Tapes* stages. *Grenzhorizont* (Germany). Subboreal (Blytt).
Upper Turbarian (J. G.)	Sub-Atlantic (Blytt).
Recent.	

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ROYAL PALM STATE PARK.

Live Oaks (*Quercus virginiana*) bearing resurrection ferns, tillandsias, orchids, and other epiphytes. The jointed climber is *Hippocratea volubilis*. Photograph by Roy D. Goodrich.

NATURAL HISTORY OF PARADISE KEY AND THE NEARBY EVERGLADES OF FLORIDA.

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[With 64 plates.]

Paradise Key, an island in the heart of the Everglades of Florida, is almost unique from a biological point of view, presenting as it does a remarkable example of a subtropical jungle within the limits of the United States in which primeval conditions of animal and plant life have remained unchanged by man, and thus offering a striking contrast to the keys along the coast of Florida as well as to other Everglade keys in which normal biological conditions have been greatly disturbed by destructive fires, clearing of forests, or the construction of drainage canals, which not only affect the original physical conditions, but at the same time permit aquatic animals and plants previously unknown to penetrate into the Everglades. The region is also remarkable for the fact that it is a meeting place for many temperate and tropical types of plants and animals. On this account and from the fact that it offers a virgin field for collectors in most branches of natural history, it seems of the highest interest and importance that a careful study of its biological features should be made.

The writer was directed by the Secretary of Agriculture to make a survey of the region, which was begun in September, 1917, and resulted in collections in nearly all branches of natural history, the material of which has been studied and classified by specialists and deposited in the collections of the Smithsonian Institution, the United States National Museum, the Bureau of Entomology, and the Biological Survey.[1]

It is impossible within the limits of the present paper to give a detailed account of the various species of plants and animals collected, or to treat fully of the climatic, physical, and ecological con-

[1] For hospitality and aid during the survey the writer acknowledges indebtedness to those in charge of Paradise Key, particularly to the Park Warden, Mr. Charles A. Mosier, a born woodsman and accomplished naturalist.

ditions of Paradise Key, but the writer hopes to portray some of the most interesting animals and plants of the key itself as well as of the surrounding Everglades, and to call attention to their interrelationship and interdependence, in the parts which they play as hosts or guests, parasites or victims, food or feeders. Among the groups considered will be plants of the marshes and sloughs, the forest trees and their epiphytal covering of orchids, resurrection ferns, and bromeliads; climbing lianas, which here reach giant proportions; the native palms of southern Florida, and the plants peculiar to the pineland region, especially the saw palmetto and the interesting cycad, *Zamia floridana*.

Among the animals to be described are some of the most interesting mollusks, spiders, insects, fishes, bactrachians, reptiles, birds, and mammals; and finally an account will be given of the little-known aboriginal Indians who inhabited southern Florida at the time of its discovery by Ponce de Leon, as well as of their successors, the Seminoles, who still live in the Everglades.

ROYAL PALM STATE PARK.

The region under consideration lies in Dade County, Florida, about 90 miles south of Lake Okeechobee and 37 miles directly southwest of Miami, in latitude 25° 24′ north and longitude 80° 38′ west of Greenwich. In 1915 the State of Florida set aside Paradise Key, together with an area of adjacent swamp land, as a public park. This, together with an additional tract afterwards donated for the purpose, has received the name Royal Palm State Park. The park, which has an area of 3 square miles, includes, besides the key itself and adjacent marshland, a corner of pineland, called Palma-vista, the vegetation of which is similar to that of other pinelands of southern Florida.[1]

Paradise Key owes its preservation from fires and other destructive agencies chiefly to its isolation and to a deep slough near its eastward border which never becomes dry, even during periods of the greatest drought. Its conversion into a state park insures its conservation as a plant reserve and bird sanctuary and as a permanent field for biological research. Similar measures have been taken in other parts of the United States, and it is hoped that the example will be widely followed.

Dr. H. C. Oberholser, of the United States Biological Survey, in commending the creation of this park points out that the refuge which it offers to birds is one which is very greatly needed in southern Florida, and that its location is admirable for the purpose of preserving the wild life of the region.

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[1] For an account of the creation of Royal Palm State Park the reader is referred to the account of Mrs. W. S. Jennings in the Tropic Magazine of April, 1916, and to an historical sketch of Paradise Key by Dr. J. K. Small in the Journal of the New York Botanical Garden, vol. 17, p. 43, 1916.

"The decrease of many species of birds," he says, "has been so marked in recent years that it is of great importance to have for them places where they can breed in undisturbed seclusion. If there do not already exist colonies of herons on this reservation, it would be very desirable to induce these birds, if possible, to take up their residence in the swamps, which I understand are a part of the park, so they could be protected, as they must be, if the various species of heron are to be preserved from extinction. For many birds, also, the Royal Palm State Park should prove to be a desirable haven and refuge, and it will undoubtedly help to preserve from extinction many of the interesting species that inhabit southern Florida."

CLIMATE AND RAINFALL.

Southern Florida, though usually blessed with an almost tropical climate, is sometimes subject in the winter months to severe storms from the north, in which the thermometer falls below the freezing point. But this is also true of some parts of the island of Cuba, which has repeatedly suffered frosts that have done great damage to the more tender vegetation. Along the coast, where the influence of the warm Gulf Stream is felt, much less damage has been done than further inland. That these occasional cold spells have not seriously injured the vegetation of Paradise Key is shown by the presence in its flora of noble royal palms more than 100 feet high, tropical orchids, and other tender plants, and insects belonging to types essentially tropical. On the other hand many temperate species, both of plants and animals, extend their range southward to this region; although, as far at least as the animals are concerned, the temperate species are here represented by varieties or subspecies which take the place of the northern types.

Generally speaking, there is a rainy season during the summer and autumn and a dry season during the winter months, but the limits of these seasons are not constant or well defined. During the rainy season the Everglades are flooded with water, while in the dry winter months they are dry enough to be crossed on foot. The accompanying illustrations (pl. 1) show Paradise Key in the distance with the Everglades, both dry and flooded, in the foreground.

PHYSICAL GEOGRAPHY OF THE EVERGLADES.

The Everglades owe their characteristic features of marsh, sloughs, and shallow ponds, to their recent origin and their slight elevation above the sea level. Their general surface is not high enough to permit the formation of deep valleys by eroding streams; and the water appears to ooze slowly seaward, on the west side toward the southwest and on the east side toward the southeast.[1]

[1] See Sanford, Samuel. The topography and geology of southern Florida, in Second Annual Report of the Florida State Geol. Survey, p. 189. 1909.

The rock which underlies the Everglades and appears on the surface on the keys and pinelands of southern Florida is known to geologists as Miami oolite. Its outcrop at Long Key, the great rock barrier adjacent to the northern boundary of Royal Palm State Park, as well as at other points, was noticed by Army officers at the time of the Seminole War. Specimens from the vicinity of Paradise Key in the collection of the United States National Museum contain fossil bivalve shells; others (pl. 2) contain vermicellilike casts of annelids, and others hollow tubes, apparently formed by crustaceans in soft mud, now lined with crystalline calcite. This oolitic limestone, as Dr. T. Wayland Vaughan has pointed out, is not of animal origin, but a chemical precipitation of calcium carbonate in the form of minute granules; it plays a much greater part in the construction of Florida reefs than corals.[1] It was originally deposited in a shallow sea, just as similar sediment is now being precipitated in the Bahama Islands. Dr. Karl F. Kellerman, of the Bureau of Plant Industry, made a careful bacteriological study of samples of water and calcareous mud from the ocean bottom near the Bahamas and the Florida keys. He found the water laden with calcium bicarbonate and filled with certain bacteria which liberated ammonia. The action of the ammonia on the calcium bicarbonate caused a precipitation of calcium carbonate, which assumed the form of oolite. The bacterial origin of calcium carbonate had previously been suggested by the late George H. Drew of the Carnegie Institution, who succeeded in isolating an organism which he named *Bacterium calcis*. Doctor Kellerman repeated his experiments and confirmed his observations, referring the above-mentioned organism to the genus Pseudomonas, under the name *Pseudomonas calcis*.[2]

WATER PLANTS.

The deep slough to the eastward of Paradise Key (pl. 3), which has already been mentioned as its chief protection from destructive agencies, is filled with a dense growth of water plants: yellow water lilies, or spatter-docks (pl. 4); Sagittarias, with broad, three-petaled white flowers (fig. 1); pickerel weed, with spikes of blue flowers (fig. 2); water arums (fig. 3) related to our jack-in-the-pulpit and with roots equally filled with needle-like raphides which burn the mouth like fire; white-flowered floating hearts (fig. 4) resembling miniature pond lilies, but not botanically related to them; and tall water weeds (*Oxypolis filiformis*) belonging to the same family as the celery, but with hollow, quill-like tubes for leaves.

[1] See Vaughan, T. Wayland. Sketch of the geologic history of the Florida coral reef tract and comparison with other coral reef areas. In Journ. Wash. Acad. Sci. 4: 26. 1914. See also "Corals and formation of coral reefs" by the same author, in the present volume.

[2] See Kellerman, Karl F., and Smith, N. R., Bacterial precipitation of calcium carbonate. Journ. Wash. Acad. Sci. 4: 400. 1914.

At first glance these water plants appear to be of no economic significance; but it is they which make animal life possible in the

FIG. 1.—*Sagittaria lancifolia.* a, Growing in damp soil; b, growing in water. Much reduced.

FIG. 2.—Blue-flowered pickerel weed, *Pontederia cordata.* Much reduced.

Everglades. Aquatic insect larvæ and water snails and bivalves which feed on their roots and submerged stems, yield food to small fishes; fishes, crustaceans, frogs and surface insects are the food of larger fishes, snakes, alligators, and birds. One of the most common occurrences is to see a magnificent osprey swoop down upon what appears a grassy prairie and rise with a good-sized fish in its talons.

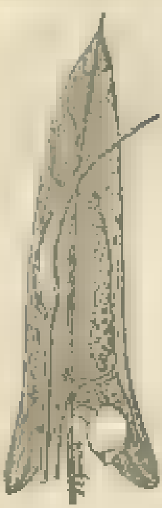

FIG. 3.—Water arum, *Peltandra virginica.* Its acrid starchy root, called tuckahoe, when thoroughly cooked was eaten by the Indians of Virginia. Much reduced.

FIG. 4.—Floating heart, *Nymphoides aquaticum*, a dainty water-plant of the Everglades.

FIG. 5.—Germinating seed of the white spider-lily, *Crinum americanum*, showing the peculiar development of the bulb. Half nat. size.

In addition to the plants just mentioned are numerous sedges (pl. 5) and grasses (pl. 6). No traveler in the Everglades will forget the terrible "saw-grass" (pl. 7), which is really not a grass but a sedge, the leaves of which as seen under the lens (pl. 8) are armed with very sharp, fine cutting teeth. Among the marsh ferns are *Acrostichum excelsum*, with coarse,

leatherlike fronds, and *Blechnum serrulatum*, with much thinner fronds which soon wilt when gathered. There is a beautiful Crinum, with white spiderlike flowers, and thick, fleshy seeds which have a peculiar method of germinating (fig. 5); stately cat-tails, bladderwort with fine, dissected aquatic leaves, and many other characteristic water plants, specimens of which have been deposited in the United States National Herbarium. It is interesting to note the absence of the water hyacinth and water lettuce which impede navigation in the streams and lakes of northern Florida.

MARSH SHRUBS.

Paradise Key is bordered by a growth of marsh-loving shrubs; among them, the amphibian willow; alligator apple (pl. 9); the wax myrtle, which yields wax from which candles may be made; the fragrant swamp bay, with an aromatic fragrance like that of bay rum; a magnolia with white flowers and silver-lined leaves; cocoa plums with edible fruit and a Baccharis (pl. 10), which bears the pistillate flowers on one bush and the staminate flowers on another. Not far from the park are small islets covered with thickets of mangroves with branching, stiltlike roots; and button mangroves (pl. 11) with nectar glands at the base of the leaf blades; and in several places are small groves of cypress (pl. 12), similar to those of the Dismal Swamp, but not nearly so extensive.

FIG. 6.—GUMBOLIMBO, *Elaphrium simaruba*; LEAVES AND UNRIPE FRUIT. HALF NAT. SIZE.

FOREST TREES AND SHRUBS.

It will not be possible within the limits of this paper to enumerate the forest trees, most of which are essentially tropical. The largest, however, is the magnificent live oak (*Quercus virginiana*) of our Southern States (pl. 13), which sometimes spreads its moss-covered branches over an area 200 feet in diameter. The gumbolimbo (*Elaphrium simaruba*) gets its odd name from the Jamaica negroes, a corruption of *goma elemi*, the Spanish name of an aromatic balsam which exudes from its bark when wounded. In the Antilles it is sometimes called West Indian birch, on account of its papery red bark which peels off like that of certain birches; and in some parts of Spanish America its common name is *palo mulato*, from the color of its trunk. It bears transplanting remarkably well; sometimes large trees are taken up from hammocks and planted in private grounds, where they at once establish themselves. The fruit (fig. 6) is much relished by crows and other birds.

Other striking trees are the satinleaf (pl. 14) which takes its name from the golden brown, satinlike lining of its leaves; the laurel-cherry of the West Indies, the leaves of which when crushed have the characteristic bitter-almond odor of prussic acid; a beautiful mimosa-like Lysiloma, usually called wild tamarind, with fernlike foliage and smooth white trunk; the mastic tree, or wild olive (fig. 7); the bois-fidèle (incorrectly translated "fiddle wood") with racemes of fruit shown in figure 8, and the pigeon plum (*Coccolobis laurifolia*).

FIG. 7.—MASTIC TREE, *Sideroxylon foetidissimum* JACQ. INFLORESCENCE, FRUIT, AND SEEDS. HALF NAT. SIZE.

Of special interest is the strangling fig, *Ficus aurea*, which begins life somewhat like a mistletoe, sprouting from a tiny seed dropped on the limb of a tree. It soon sends down threads which take root when they reach the ground, and which grow together wherever they touch one another, forming a meshwork about the trunk of the host which is slowly strangled to death (pl. 15). This may well be designated the snake tree, or constrictor, of the vegetable world. Similar trees of the genus Ficus are found in many tropical countries. Botanically they are related to the many-trunked banyan of the East Indies, as well as to the familiar rubber plant of our conservatories.[1]

FIG. 8.—BOIS FIDÈLE, *Citharexylum fruticosum*; FRUIT AND LEAF. HALF NAT. SIZE.

Another forest monster is the poison tree, *Metopium toxiferum*, a giant sumach with a smooth spotted trunk, the sap of which acts very much like the poison ivy of our woods, causing eruptions on the skin. This tree is tropical in its distribution. On the south shore of the island of Cuba a surveying party of officers and men of the U. S. S. *Paducah* employed, in May, 1912, in clearing a base line near Caballona Channel, were badly poisoned by this tree, the effects of which they described as worse than those of *Rhus toxicodendron*. Notwithstanding this the berries are eaten with relish by many species of birds at a time when other fruits are scarce.

[1] Students of phytogeography are referred to the work of Dr. John W. Harshberger, of the University of Pennsylvania, on "The vegetation of South Florida," published in the Transactions of the Wagner Free Institute of Science of Philadelphia, vol. 7, part 3, October, 1914. In this work the plants of southern Florida will be found grouped according to plant formations or associations.

It is interesting to note that a closely allied tree, *Rhus vernicifera*, yields the celebrated Japanese lacquer, a kind of varnish prepared from the very poisonous milk juice, or latex, which exudes from incisions made for the purpose. Violent poisoning from this latex is common among the workmen engaged in manufacturing the lacquer, which is one of the most indestructible varnishes known in the arts. Stories are told of jewelers or cabinetmakers who, engaged in repairing very old pieces of lacquer ware, have been severely poisoned by the dust.

Among the smaller trees and forest shrubs of Paradise Key are several belonging to the Myrtle family, including the white stopper, naked stopper, spicewood, and the myrtle-of-the-river, the latter (*Calyptranthes zuzygium*) with opposite glossy leaves and clusters of fruit resembling blueberries. In addition to these are the paradise tree, or bitterwood; soapberry tree; *Krugiodendron ferreum*, or West Indian ironwood; marlberry; and a holly (*Ilex cassine*) with red berries but with leaves devoid of prickles, sometimes confused with the more northern species from which the Indians of Florida made their "black drink," but quite distinct from it. Specimens of all these together with other interesting shrubs and small trees from this locality have been deposited in the United States National Herbarium.[1]

CLIMBING PLANTS.

Many of the climbing plants are interesting from their manner of clinging to the trees which support them. *Hippocratea volubilis*, which, on account of its conspicuous swollen nodes, may be called the "jointed liana," takes root wherever it touches the ground, forming loops which trip up the unwary traveler, or perhaps catch him under the chin as he passes through the jungle. Its opposite, armlike branchlets, which terminate in tendrils, clasp the tree trunks as the plant makes its way upward to the light. When it has established itself and spread over the branches, the arms, no longer of use, break off at the shoulders and leave the vine hanging like a great rope usually at some distance from the trunk, causing the observer to wonder by what means it had reached its point of support (see frontispiece). This plant covers the crown of a tree so thickly that its host is sometimes crushed under its weight. According to the park warden, more trees are overwhelmed and brought to earth by this incubus than by storms or destructive parasites.

Among the other climbers are several wild grapes and plants closely related to them, one of the most interesting of which, *Cissus*

[1] For botanical descriptions of these plants the reader is referred to Dr. J. K. Small's Flora of Miami, in which most of them will be found.

sicyoides, is sometimes called the water liana or hunters' vine, in the West Indies. If a section is cut from the stem of this plant, a cool, refreshing drink may be obtained from its sap by applying the mouth at one end and slightly tipping up the other. Its succulent stems are often found gnawed through by some animal; but, instead of dying, the plant continues to live and soon sends down cordlike roots which penetrate the earth like those of certain epiphytes. Among those which hold on by recurved prickles are *Erythrina arborea*, *Guilandina crista*, and *Pisonia aculeata*, all of them plants which usually occur elsewhere as scrambling shrubs, but which here become climbers. The first of these (pl. 16), which belongs to the Bean family, has bright red, slender flowers and pods constricted between the bright scarlet seeds; the second, belonging to the Cassia family, is the plant which bears the well-known polished gray, stony seeds called nicker nuts; the third, belonging to the Four-o'clock family, has peculiar, slender fruits (fig. 9) bearing five longitudinal rows of prickly glands by means of which they adhere to the plumage of birds and the fur of mammals. This plant often forms dense thickets, in trying to penetrate which any creature will be lacerated by the stout, sharp, recurved thorns which arm its branches and which give it its common names "cockspur," "pull-and-hold-back," and "wait-a-bit vine." On Paradise Key *Pisonia aculeata* sometimes reaches gigantic dimensions, climbing to the tops of the highest trees. Plate 17 is reproduced from a photograph, made for the author in September, 1917, of a specimen discovered by Mr. Mosier, with a stem 40.5 inches in circumference at a distance of 7 feet from the base.

FIG. 9.—COCKSPUR, *Pisonia aculeata*; FLOWERS, GLANDULAR FRUIT, AND RECURVED SPINES WHICH AID IT IN CLIMBING. REDUCED.

The tropical zarzaparillas ("climbing brambles") are represented by several subtropical species, the most remarkable of which is *Smilax laurifolia*, the "swamp bamboo brier," a lofty climber which grows in marshy places. A photograph of its thick, bamboolike root stocks is shown on plate 18. A closely allied species, *Smilax auriculata*, growing outside the park in drier situations, was the principal source of a delicious jelly, called "red coontie," formerly prepared by the Indians of the southeastern United States from the fecula contained in its root stalks and tubers.

ORCHIDS.

Most of the orchids of Paradise Key are modest and inconspicuous when compared with their gorgeous relatives in our conservatories; but some of them are prized for their odd forms or their fragrance, and all of them are attractive both to botanists and to laymen. Some of the most interesting are shown on plate 19. *Spathiger rigidus* (fig. 1), a creeping epiphyte widely spread in the West Indies, with pale, yellowish-green flowers, blooms continuously throughout the greater part of the year. The spider orchid, *Auliza nocturna* (fig. 2), also West Indian in its distribution, takes its specific name from the exquisite fragrance which its large, white, narrow-petaled flowers exhale toward nightfall. The shell orchid, *Anacheilium cochleatum* (fig. 3), was first designated by old Hans Sloane in 1707, as a "mistletoe with a bulbous root and a showy, larkspurlike flower." The chintz-flowered orchid, *Oncidium undulatum* (fig. 4), has odd-looking, mottled flowers, also described by Sloane, who likened them to patches of Dutch chintz. *Macradenia lutescens* (fig. 5) is a modest, little plant with drooping flowers dotted with purplish brown. The marsh orchid, *Oncidium sphacelatum* (fig. 6), usually found growing on the edges of swamps, has conspicuous, yellow flowers spotted with wine color.

OTHER EPIPHYTES.

In addition to the epiphytal orchids other plants are found growing on the limbs and trunks of forest trees, among them the resurrection fern, which curls up during periods of drought and uncurls its fronds when moisture returns; a fleshy leaved Peperomia which creeps along the tree trunks; the well-known Dendropogon, or Spanish moss, which hangs in festoons from the branches (pl. 20); and its relatives of the pineapple family, the stiff-leaved bromeliads (pl. 21). It is interesting to note in connection with the latter that the bases of the leaves of many bromeliads collect water in which insects lay their eggs and undergo their transformations. In some parts of tropical America, in regions remote from water, certain dragon flies and even frogs habitually lay their eggs in such reservoirs, which have been collectively called an epiphytal swamp region, which has the important advantage over a true swamp that it never dries up.

In addition to the marsh ferns and the epiphytal resurrection fern already mentioned there are several other interesting species, including a delicate, little, filmy fern (fig. 10) growing among moss on the trunks and limbs of trees; the epiphytal grass fern, *Vittaria lineata*, and golden Phlebodium, with large fronds lobed like an oak leaf and dotted beneath with conspicuous sori (pl. 22), often

found growing from the old leaf axils on the trunks of cabbage palmettos; the strap fern, *Campyloneuron phyllitidis*, with undivided, strap-shaped fronds; the well-known "Boston fern" of our conservatories (*Nephrolepis exaltata*), and the closely allied sword fern (*N. biserrata*). Other species included in the flora are the brake, *Pteridium caudatum*; the beautiful royal fern (pl. 23); *Anemia adiantifolia* (pl. 24); and the wood ferns, *Dryopteris patens* and *D. augescens*.[1]

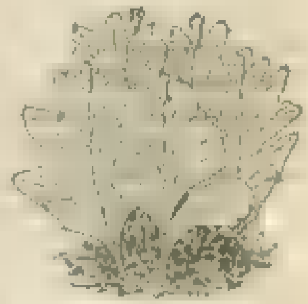

FIG. 10.—EPIPHYTAL FILMY FERN, *Trichomanes punctata*. ENLARGED.

FLORIDA PALMS.

Among the native palms of peninsular Florida are the royal palm (pl. 25) which has given its name to Royal Palm State Park; the saw palmetto so characteristic of the pinelands; the saw cabbage palm, *Paurotis wrightii*, of coast hammocks (pls. 26 and 27) which has sometimes been confused with the preceding; the cabbage palmetto, or cabbage palm (pl. 28); the small-seeded, dwarf, blue-stem palmetto, *Sabal glabra*, of northern Florida; the large-seeded, dwarf palmetto, *Sabal etonia*, of southern Florida; the silver palm of the pine woods near Miami and Homestead, *Coccothrinax argentea;* the Florida thatch palm, *Thrinax floridana;* and the brittle thatch, *Thrinax microcarpa*, which occurs at the lower extremity of the peninsula. The majority of these species are found also on the Bahamas and other islands of the West Indies; the large-fruited *Sabal etonia*, however, is endemic. The coconut palm is not a native of Florida, but may be regarded as a naturalized citizen of the State. In the accompanying illustration (pl. 28) are shown the seeds of most of these palms which differ so strikingly that they will serve to identify the various species. In addition to the seeds themselves the plate includes the dropping of a bird in

FIG. 11.—CABBAGE PALM, *Sabal palmetto*, SHOWING DECURVED LEAF-BLADES.

[1] For further information regarding Florida ferns the reader is referred to the beautiful little pocket manual of Dr. J. K. Small, entitled "Ferns of tropical Florida, 1918.

which a number of Thrinax seeds occur. Seeds of the royal palm may have found their way to the park in the same way, dropped by migrating birds from Cuba. In southern Florida trees of this species as well as those of the cabbage palm and the introduced coconut are sometimes used with great effect to form avenues. It is interesting to note that the leaves of the cabbage palm, though usually called fan-shaped, really have a short, decurved midrib (fig. 11). This feature, together with certain peculiarities of the inflorescence, leads Mr. O. F. Cook of the Bureau of Plant Industry to separate several species usually included under Sabal into a distinct genus which he has named Inodes.

PINELAND FLORA.

The only pine growing in the vicinity of Paradise Key is *Pinus caribaea* (pl. 29). This is one of the species which gives its name to the Isle of Pines on the south coast of Cuba. It covers vast areas of southern Florida (pl. 30), accompanied by an undergrowth peculiarly its own. Next to the saw palmetto the most remarkable plant of the pinelands is a cycad, *Zamia floridana*, from which the Seminoles make a starch, commonly called coontie, or Florida arrowroot.

The ancestors of this plant and its congeners can be traced back to the giant cycads of the Carboniferous age. Among its relatives are the "sago palms," *Cycas circinalis* and *Cycas revoluta*, so well known to horticulturists.[1] Closely allied species of the same genus occur in the West Indies, and of related genera in Mexico, Central America, and Africa. All of them are remarkable for their peculiar method of cross-fertilization; and nearly all of them are valuable as sources of food.

Zamia and its allies occupy a place intermediate between flowering plants and ferns. Like the former, they bear fruit with a true endocarp or seed; but, like the latter, their sexual propagation is accomplished by means of spermatozoids provided with movable cilia, resembling those of animals. The male and female plants are easily distinguished. The inflorescence of the male plant (pl. 31) is in the form of an erect cone, shaped somewhat like an ear of maize and composed of scales which bear on their under surface numerous pollen sacs. That of the female plant (pl. 32), much thicker and relatively shorter, is composed of broad scales, each bearing a pair of ovules quite devoid of any protective covering. The pollen, borne by the wind, settles on the ovules, and sends down a tube into the tissue of the nucellus. Archegonia are formed; egg cells develop, and in the pollen tube are produced spermatozoids which fecundate the egg. The fertilization of *Zamia floridana* was studied

[1] See Bailey's Standard Cyclopedia of Horticulture, 2: 931 to 940. 1914.

by Dr. H. J. Webber. It was he who first described and figured these remarkable spermatozoids, which exceed in size those of all other living organisms.[1]

The ovules of *Zamia floridana* develop into beautiful orange-red fleshy fruits arranged about a central axis, like large grains of corn around a cob. These are at first covered by the peltate, triangular scales which bore them, but they fall off when fully ripe and form conspicuous bright-colored heaps in the pine lands where they grow. A second species of Zamia occurs in the shady woods of Paradise Key, but only male plants have thus far been found there. It has been referred by Small to *Zamia integrifolia*, a species in moist woods of middle Florida, particularly near the east coast. This species may be distinguished from *Z. floridana* by its leaflets, which are somewhat broader, and have 20–28 parallel veins, about twice as many as those of the latter. Both its leaves and its cones bear a close resemblance to those of the West Indian *Zamia media* with which it may possibly prove to be identical; while *Zamia floridana* more closely resembles *Zamia angustifolia* of the Bahamas.

Among other characteristic plants of the pinelands are the silver palm, the large-seeded *Sabal etonia*, sometimes called the goose-neck palmetto, and the tall cabbage palm, already mentioned; among the orchids, the tall, purple-flowered *Bletia purpurea* and the grass pink, *Limodorum pinctorum;* the pineland blueberry, *Vaccinium myrsinites;* the dwarf, white-flowered papaw, *Asimina reticulata*, the thorn twig, *Bumelia reclinata* (pl. 33) and the prickly, holly-leaved *Rhacoma ilicifolia*. Among the climbing plants, or twiners, are the beautiful, red-flowered morning-glory, *Exogonium microdactylum*, with flower buds resembling fuchsias; the conspicuous *Echites echites*, belonging to the Apocynaceæ, with salver-shaped flowers resembling enormous white jasmines, and a pair of long, slender seed pods inclosing silky seeds; two species of smilax, *S. bona-nox*, and *S. havanensis;* and occasional moonflowers, *Calonyction aculeatum*, climbing to the tops of trees. Among the ferns are the bracken, *Pteridium caudatum; Pteris longifolia; Anemia adiantifolia*, shown on plate 24; and in the old leaf axils of the cabbage palm *Phlebodium aureum*, on plate 23. In addition to these may be mentioned two plants which are confined to the southern Florida pinelands and do not occur elsewhere—*Chamaesyce pinctorum*, a low, spreading, hairy, small-leaved plant belonging to the Euphorbiaceæ; and the dwarf Florida privet, *Forestiera pinetorum*, belonging to the olive family, shown on plate 34.

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[1] Webber, Herbert J. Spermatogenesis and fecundation of Zamia. U. S. Dept. Agr., Bureau of Plant Industry, Bull. No. 2, 1901.

ANIMAL LIFE.

It is impossible within the scope of this paper to give a detailed account of the animals of Royal Palm State Park. The insect fauna alone must certainly include thousands of species, only a few of which can here be mentioned.

The tree snails (see pl. 35) which form such an attractive feature of the forest, though varying greatly in color, are referred by zoologists to a single species, *Liguus fasciatus*. These beautiful creatures, which spend their lives on the trunks of trees browsing upon microscopic cryptogamous plants, are air-breathing mollusks like their relatives the common snails, having their eyes on the ends of long tentacles (fig. 12) which they can fold in like the tip of a glove finger. Specimens sent by Mr. Mosier from Paradise Key are now domesticated in one of the greenhouses of the United States Department of Agriculture, having borne the trip from their native forest without apparent inconvenience. As in allied genera these animals have both sexes united in a single individual; so that each may become both a father and a mother. In mating they do not appear to discriminate as to color, for a pure white-shelled form may be seen paired with one which is yellow-banded or mottled like tortoise shell. They sometimes fall victims to another air-breathing mollusk, the cannibal snail, *Glandina truncata* (pl. 26, fig. 2), the young of which sometimes devour one another.

FIG. 12.—TREE SNAIL OF ROYAL PALM PARK, *Liguus fasciatus*, WITH BOTH SEXES ARE UNITED IN EACH INDIVIDUAL. NAT. SIZE.

Other snails of this family are the minute *Polygyra septemvolva* (pl. 36, fig. 3) and *P. uvulifera* (pl. 36, fig. 4) with flattened shells composed of many whorls coiled like a watch spring. Another little shell, *Helicina orbiculata* (pl. 36, fig. 5), is distinguished by having a little door, or "operculum," with which it closes the orifice of its shell. Among the pond snails are *Planorbis duryi* (pl. 3, fig. 6) and *Physa gyrina* (pl. 36, fig. 7), the latter with a thin polished, left-handed shell.

The great marsh snail, *Ampullaria depressa*, is of interest as the principal food staple of the Everglade kite, already mentioned. The colored illustration in the center of plate 35 was made from a living specimen sent to Washington from Royal Palm State Park. Its eggs, resembling flesh-colored pearls, are attached to the stems of water plants (fig. 13). Last of all must be mentioned the little bivalve, *Musculum partumeium* (pl. 36, fig. 9), which has a thin, orbicular shell through which its pulsating heart can be seen. It is

an interesting little creature, actively climbing among the submerged stems and leaves of plants, breathing in and expelling water by means of a double-barreled siphon.

Of greater economic importance than the large marsh snails above mentioned are the crawfishes of the Everglades, which are eaten in great quantities by many marsh birds, especially by white ibises and blue herons. Specimens collected in the immediate vicinity of Paradise Key (pl. 37) were identified by Mr. W. L. Schmitt of the United State National Museum as *Cambarus fallax* Hagen.

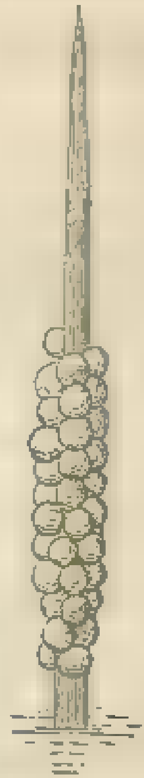

FIG. 13.—EGGS OF MARSH SNAIL, *Ampullaria depressa*, ON STEM OF WATER PLANT. NAT. SIZE.

The centipedes and scorpions of Royal Palm State Park are represented in the writer's collection by a single species each. The first, identified by Mr. O. F. Cook as *Theatops postica*, is interesting on account of its peculiarly hooked and thickened last pair of legs. Its bite, though poisonous, is not dangerous. The scorpion identified by Dr. Nathan Banks as *Centrurus gracilis*, like all of its allies, has pincerlike palpi resembling the claws of a crawfish, and a long tail terminating in a poison sting (pl. 38). Perhaps the most interesting feature of its anatomy is a pair of minute, diverging, comblike organs borne on its ventral side just behind the last pair of legs (fig. 14). The function of these little combs is not yet understood. An ally of the scorpions, which may be regarded as intermediate between them and the spiders, is the giant whip scorpion, *Mastigoproctus giganteus*, shown on plate 38. Its enormous palpi suggest the branching mandibles of a large stag beetle. In the scorpion the front legs are the shortest pair, while in the whip scorpion they are greatly elongated; but the greatest difference is in the tail, that of the whip scorpion being entirely devoid of a sting. Even the fangs of this ugly creature, so much dreaded by the natives wherever it is found, are said by Doctor Banks to be devoid of poison. When attacked it emits an acid, vinegarlike odor, from which the name *vinaigrier* has been given it by French creoles in the Antilles.

FIG. 14.—COMB-LIKE ORGANS OF SCORPION, *Centrurus gracilis*. THEIR FUNCTION IS UNKNOWN.

SPIDERS.

Among the spiders collected on Paradise Key are several of unusual interest. One of them, *Nephila clavipes*, constructs a beautiful web composed of fine, silken threads which glisten in the sun like burnished gold. Its silk has been woven into fabrics. A second species, *Miranda aurea*, forms a peculiar egg cocoon resembling a miniature paper balloon. A third species, *Phidippus audax*, spins no web at all, but catches its prey by jumping upon it and drags it backward to its den. It has iridescent jaws and bright red eyes, from which it may well take its name of "ruby-eyed monster."

The life histories of many spiders as well as of certain groups of insects are so tragic that the writer ventures here to repeat what has already been expressed by Maeterlinck; since it is so strikingly applicable to conditions on Paradise Key. With other classes of animals and even with plants man feels a certain kinship, but spiders and insects are not of his world; their strange habits, ethics, and psychology seem to belong to some other planet, where the conditions are more monstrous, more active, more insane, more atrocious, more infernal than in our own. It is hard for us to believe that these monsters are conceptions of that Nature whose privileged children we love to imagine ourselves to be. We are horrified at the atrocities they commit; their clandestine thefts, their ignoble parasitism; the bold robberies, the murders, cannabalism, mariticide, for which many of them seem especially adapted. Frightfulness and ruthlessness appear to be a very part of their nature; and we stand appalled when it dawns upon us that these creatures are far better armed and equipped for their life's work than we for ours. We almost dread them as our rivals and ultimate successors, as the dominant inhabitants of this globe.

THE SPIDER THAT SPINS TEXTILE SILK.

Outside the gauze screen of the park lodge veranda the writer noticed a geometrical spiderweb, in which insect victims of all descriptions had been ensnared, ranging in size from mosquitoes to huge grasshoppers and dragon flies. In the center of the web was the lady spider who had constructed it, and near its margin the diminutive male, who seemed to be hanging 'round in a shiftless sort of way, subsisting on such scraps of food as she might leave. Specimens of these spiders (fig. 15) were identified by Mr. C. R. Shoemaker of the United States National Museum as *Nephila clavipes*, a species celebrated from the fact that its silk has actually been woven into fabrics, specimens of which, in the form of bed curtains, were exhibited at the Paris Exposition. In order to obtain the silk a large number of females were kept in captivity, each by

herself in an iron ring isolated by water, fed with flies, and deprived of her silk each day. Each of the cocoons of this spider contains from 500 to 1,000 eggs. The newly hatched young show cannibalistic propensities from the very beginning; for they not only feed upon small insects which come in their way, but they devour one another. After two or three weeks in a web shared in common they scatter and each female proceeds to spin a web for herself. From this time they must be kept separate, or they would eat one another. In removing the silk the spider is gently seized and secured in a pair of stocks, and the thread steadily and carefully pulled from her spinnerets until it is exhausted. In this way a spider is made to yield about an ounce of silk during the summer. The thread is smoother, finer, and more brightly colored than that of the silkworm.[1]

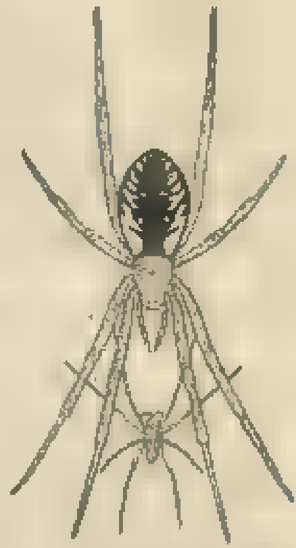

Fig. 16.—*Miranda aurantia*, adult female and male. The female often devours her pygmy bridegroom at the end of the honeymoon. Nat. size.

As shown in the illustration, the male is much smaller than the female, from which it is also distinguished by its peculiar palpi, which correspond to claws of scorpions and the enormous pincers of the whip scorpion shown on plate 36, but which are in the spiders specialized into sexual organs. Doctor Wilder, who was the first to breed this species for their silk, contrasts the handsome female with the insignificant male, who neither toils nor spins, and who keeps at a respectful distance except when mating, and even then it is not unusual for the ogress bride to eat him up.[2]

Fig. 15.—*Nephila clavipes*, adult female and male. Its golden yellow silk has been spun and woven into bed curtains. Nat. size.

The Golden Miranda (also known as *Epeira*, or *Argiope riparia*) is a beautiful, black and yellow spider of the marshes (fig. 16). The female is nearly an inch in length, while the male is only about one-fourth as long, similarly colored, but with the markings less distinct and with very large palpi. The females make webs about 2 feet in

[1] See Emerton, J. H., The Structure and Habits of Spiders, pp. 70–72. 1878.
[2] See Wilder, B. G., How my new acquaintances spin. Atlantic Monthly, 18: 130. 1866.

diameter in the marsh grass or bushes, with an up-and-down zigzag white band across the middle and a round thick spot where she takes her station. In the autumn she lays her eggs in a large, balloon-shaped cocoon like that already described (fig. 17). Both the eggs and the newly hatched young are subject to the attacks of parasitic insects.

FIG. 17.—BALLOON-LIKE EGG-SACK OF *Miranda aurantia*. HALF NAT. SIZE.

TERMITES, OR WHITE ANTS.

Unlike their African relatives, which build great mounds, the termites of Paradise Key infest dead wood (pl. 30) and are therefore apt to escape notice except during the period of swarming. At least four species have been collected in the park by Mr. Thomas E. Snyder, office of Forest Insect Investigations, United States Department of Agriculture. The social organization of these little insects is of special interest. In addition to perfect winged males and females, and wingless workers and soldiers, there are nymphal and larval forms of males and females which never become winged. (See fig. 18.) The most interesting feature in connection with these little insects is their social life and the subdivision of labor in their communities. Though commonly called "white ants," and often referred to by travelers as "ants," they are not related to the true ants, but belong to the order Platyptera, more nearly allied to the May flies, dragon flies, and ant lions. One of the most remarkable phenomena of insect biology is the similarity of the functions of corresponding "castes" in such widely separated groups as the termites on the one hand and the ants and social bees on the other. Both groups of insects live in communities and have their queen mothers, royal consorts, and specialized workers, which are sexually imperfect. In the bees, however, the workers are imperfect females, while among the termites here considered, the castes of both soldiers and workers are composed of imperfect males as well as females. Another important point of difference is that newly hatched

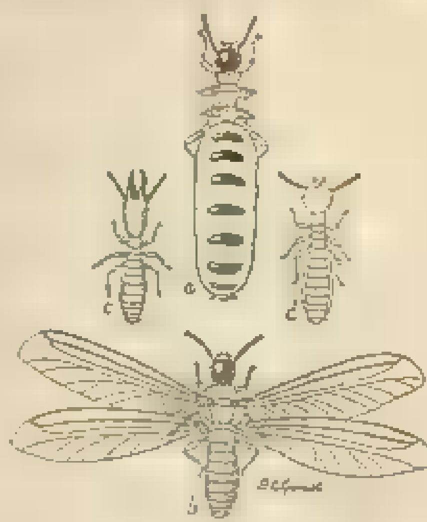

FIG. 18.—WHITE ANTS, *Leucotermes flavipes*. *a*, PREGNANT QUEEN; *b*, WINGED MALE; *c*, SABRE-JAWED SOLDIER; *d*, BLIND WORKER AND NURSE. ENLARGED.

bees and wasps are helpless, footless grubs, while the young termite when it emerges from the egg is an active, crawling, six-legged creature, which soon begins to feed itself.[1]

DRAGON FLIES AND DEMOISELLES.

On plate 40 are shown five species of Odonata from Paradise Key, identified for the writer by Miss Bertha P. Currie of the United States National Museum, and her brother, Mr. Rolla P. Currie. While sitting on the screened veranda of the park lodge it was pleasant to watch these graceful insects, like squadrons of miniature airplanes, waging incessant war upon the besieging mosquitoes. It is not possible within the limits of this paper to speak of the early aquatic stages of these insects and their transformations. Attention has been called in connection with the Bromeliaceæ to the fact that in tropical America there are certain species which lay their eggs and undergo their transformations from the larval stage to the perfect insect in the water collected by the leaves of epiphytal plants of that family. In this connection the reader is referred to the recent work of the Calverts on the natural history of Costa Rica.[2] Some of the species shown in the illustration are quite widely distributed, but *Gynacantha nervosa*, the largest of the collection (pl. 40, fig. 2) is a very rare tropical species hitherto represented among the North American Odonata of the United States National Museum by a single specimen; and the dainty little demoiselle, *Argiallagma minutum* (pl. 40, fig. 4), which is even rarer, is quite new to the collection.

MARGARODES, OR GROUND PEARLS.

In the black soil of the forest, often in the clefts of limestone penetrated by the roots of plants, quantities of little opalescent globules are sometimes found. These beautiful little objects are the shells of Coccidae or scale insects, known as Margarodes or ground pearls. They occur also in the West Indies, on some of the islands of which they are strung into necklaces and made into purses. Very little is known concerning their life history. It was formerly thought that they occur on the roots of plants, but Mr. W. T. Swingle, who was the first to find them within the limits of the United States, in January, 1895, called attention to the fact that in no case did he find them attached to roots. In the accompanying illustrations, plate 41 shows a colony found by C. A. Mosier on Paradise Key, in

[1] For a detailed account of these interesting insects the reader is referred to the paper of Mr. Thomas E. Snyder, entitled "Biology of the termites of the eastern United States," published by the U. S. Department of Agriculture Bureau of Entomology Bulletin No. 94, pt. 2, 1915.

[2] Calvert, Amelia Smith, and Philip Powell. A Year in Costa Rican Natural History, pp. 230-248. 1917.

fissures of oolitic limestone. On plate 42 are shown cysts, enlarged 6 diameters; and on plate 43 are shown necklaces and loose ground pearls in the collection of the Bureau of Entomology, collected by the late Prof. C. V. Riley and Mr. H. G. Hubbard in the West Indies.[1] This plate is reproduced from a photograph kindly furnished the writer by Dr. L. O. Howard, Chief of the Bureau of Entomology.

The family Coccidae, to which these interesting ground pearls belong, includes some very pernicious as well as some very valuable species. The former, known as scale insects, do great injury to fruit trees and other plants. Among the latter are several which are the sources of valuable dyes and lacs: the Mexican cochineal, which has become domesticated and is reared on certain species of Cacti; the classic kermes of the Old World, from which "crimson" (*carmesin*) takes its name and which was used for dyeing the curtains of the Jewish tabernacle; the "scarlet grains" of Poland, gathered from the roots of *Scleranthus perennis;* another species, infesting the roots of *Sanguisorba sanguisorba*, used by the Moors as a source of a beautiful rose color with which they dye fabrics of wool and silk; the Asiatic lac insects, which produce commercial lac, from which shell-lac, sealing wax, and lac dyes and certain lake pigments are derived. It is interesting to note that among the principal trees infested by these lac insects are certain species of Ficus; and that the *Ficus aurea*, the strangling fig of Paradise Key, is also infested by a Coccus, which Mr. Harold Morrison of the Federal Horticultural Board has identified as *Coccus elongatus*. An attempt might be made to introduce lac insects from India into southern Florida, to see if they would thrive on the native species of Ficus.

BUGS.

Among the Hemiptera of Paradise Key determined for the writer by Mr. E. H. Gibson of the Bureau of Entomology are *Acrosternum hilaris* (pl. 44, fig. 8), a smooth, green insect allied to our squash bugs; *Leptoglossus phyllopus* (pl. 44, fig. 7), sometimes called the "leaf foot"; and *Metapodius femoratus* (pl. 44, fig. 9), the "thick thigh," which punctures fruits and sucks their juices. Less conspicuous are the brown bug, *Euschistus ictericus*, and *Edessa bifida*, the latter marked on the back by a whitish U-shaped figure. To this same class of insects belong the various tree hoppers, some of which are of odd shapes, simulating thorns and other natural objects.

ROACHES AND GRASSHOPPERS.

Among the Orthoptera of Paradise Key, determined for the writer by Mr. A. N. Caudell, United States National Museum, are *Eurycotis*

[1] See Proceedings of the Entomological Society of Washington, 3: 148. 1894.

floridana (pl. 45, fig. 6), a large roach; *Gonatista grisea* (pl. 44, fig. 6), a mantis resembling the "praying mantis" of southern Europe in form, but differing from it in color, and distinct from it generically; a walking stick, *Thesprotia graminis;* and several grasshoppers, or locusts, including *Romalea microptera* (pl. 44, fig. 10, and pl. 45, fig. 4), remarkable for its great size and gaudy colors. In addition to these may be mentioned a katydid, *Scudderia texensis* (pl. 44, fig. 9) and a cricket, *Gryllus assimilis* (pl. 44, figs. 1 and 2).

Fig. 19.—Newly molted *Eurycotis floridana*, about to devour its cast-off exoskeleton. Half nat. size.

A large specimen of the above-named roach was observed on the lodge veranda in the process of molting. Motionless, head downward, holding on to the side of the house by its six feet, its shell proceeded to split and an exact replica of the insect gradually emerged from it, but it was pure white except its two little black eyes, which were almost concealed by the anterior edge of its shieldlike thorax. At first it was soft and helpless, but it soon showed signs of life, and turning about (see fig. 19) it proceeded to devour its cast-off shell, even to the tips of the antennæ and the rigid, spiny, chitinized legs; so that there was not a vestige left of its old exoskeleton. This species, the only representative of the genus Eurycotis in the United States, is confined to Florida and Georgia. It has rudimentary wings and is incapable of flight. Its food consists of all kinds of organic substances, including textile fabrics and paper. Its only defense is a volatile, ill-smelling substance which it exudes from beneath the abdomen.

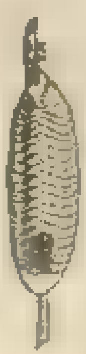

Fig. 20.—Egg case of mantis, *Gonatista grisea*. From a specimen collected by C. A. Mosier. Half nat. size.

Gonatista grisea, the common mantis of the park, presents an admirable example of camouflage; for its lichenlike mottled grayish coloration renders it almost invisible as it stations itself motionless on a branch or stem in wait for its insect prey. A specimen of its peculiar egg case, or *ootheca*, sent to the writer by the park warden, is shown in figure 20. It is almost identical in form and structure to that of its European cousin, the life history of which is even more terrible than that of the spiders; for instead of one husband, this lady Bluebeard is capable of devouring seven husbands in succession. In this connection the reader is referred to the great work of Fabre, who apropos of the mantids exclaims: "Ah! les féroces

bêtes! On dit que les loups ne se mangent pas entre eux. La Mante n'a pas ce scrupule." The details of her conduct as related by him are too horrible for translation.[1]

The Phasmidae, to which the walking sticks belong, are all wingless insects which mimic different kinds of twigs. They are slow and deliberate in their movements; they also are camoufleurs, relying for protection upon their deceptive resemblance and in some cases they emit an offensive repugnatorial spray. Unlike the mantids, they are exclusively herbivorous.[2]

Romalea microptera, the giant grasshopper already mentioned, is dimorphic in coloration. In the normal form the fore wings are bright orange dotted with black and the hind wings crimson or rose colored with a black border. The general color of the other form is black or blackish. The female of this species is shown on plate 45, figure 4, and the smaller-sized male on plate 44, figure 10. Mr. Caudell has described the means by which these insects produce their peculiar simmering noise, which he traces to certain spiracles on the side of the thorax.[3]

BEETLES AND THEIR ALLIES.

Among the most interesting Coleoptera of Paradise Key identified by the venerable entomologist, Mr. E. A. Schwarz, of the United States National Museum, are *Rhynchophorus cruentatus* (pl. 45, fig. 5), a large, black, weevil with two broad, dark red stripes on its thorax, and decurved snout (which gives to the genus its name), and antennæ jointed like elbows and terminating in broad knobs. It is allied to the genus Calandra and breeds in freshly cut or broken palmettos. The adult insect uses its snout not only for feeding but also for boring holes, into which it deposits its eggs. The larvæ—fleshy, footless grubs, with tubercules instead of legs, and thick, horny, curved jaws—burrow through the freshly cut stumps and when about to transform to the pupa stage they envelop themselves in a cocoon of twisted fibers. This species, which has hitherto been recorded but from few localities in the United States, was collected in the Royal Palm State Park on May 14, 1916, by Mr. T. E. Snyder, of the Office of Forest Insects.

Sharply contrasting with the above is the remarkably slender little weevil, *Brenthus anchorago* (pl. 45, fig. 7). It has a smoothly polished, jet black head and thorax, and its wing cases, as seen under the lens, are marked with deep parallel furrows composed of minute punctures and ornamented with two longitudinal lines of straw color.

[1] See Fabre, J. H., Moeurs des Insectes; morceaux choisis extraits des *Souvenirs entomologiques*, pp. 65–70.

[2] See Caudell, A. N., Proc. U. S. National Museum, 26: 863. 1903.

[3] See Caudell, A. N., Proc. U. S. National Museum, 26: 796. 1903.

This species has an almost straight, slender snout, and its antennæ are not elbowed like those of the Rynchophorus, but moniliform, like a necklace composed of many beads. Its life history has not been studied, but in a closely allied genus the females puncture the bark of an oak and deposit their eggs. The larva, a cylindrical grub, with three pairs of legs and an anal prop leg, bores into the solid wood.

Other Coleoptera collected in the park are a predatory tiger beetle, *Cicindela tortuosa*, dark colored above and metallic beneath; a water scavenger, *Philhydrus nebulosus;* a large click beetle, *Alaus oculatus*, which has the habit of springing up suddenly when laid down on its back; *Buprestis lineata*, whose grubs are known as hammer-heads or flat-headed borers; *Calopteron reticulatum*, with broad yellow and black bands; several lamellicorns (Scarabaeidae), including *Phileurus truncatus*, *Phileurus valgus*, the yellowish brown vine chafer, *Pelidnota punctata; Anomala marginata* Fabr., which, like the preceding, feeds on the leaves of wild grapes; the handsome, green *Euphoria limbalis;* and *Trichius delta*, easily distinguished by a delta-shaped spot on its back; several longicorns (Cerambycidae), including the twig girdler, *Oncideres cingulata*, the gumbolimbo borer, *Mallodon dasystomus* (determined by F. C. Craighead), and the very rare *Euryscelis suturalis*.

In addition to the above-mentioned species the collection includes several small leaf beetles (Chrysomelidae), several weevils infesting palmetto seeds, Calandrids injurious to maize and other grasses; and a number of minute bark beetles (*Xyleborus* spp.) belonging to the Scolytidæ, which have been described by Dr. Andrew D. Hopkins of the Office of Forest Insects. To speak of them in detail is beyond the scope of the present paper.

MOTHS AND BUTTERFLIES.

The most attractive insects of the Royal Palm State Park are undoubtedly the Lepidoptera. For the identification of those in his collection the writer is indebted to Dr. H. G. Dyar and Mr. Carl Heinrich, of the Bureau of Entomology. The order to which they belong takes its name, Lepidoptera, from the minute scales which cover the wings and give them their varied and beautiful color patterns. On plate 26 is shown one of these scales from the wing of a Papilio, or swallowtail butterfly, magnified 750 diameters; and on figure 21 the arrangement of these scales on a butterfly's wing, overlapping one another like shingles or tiles.

MOTHS.

The rarest and most interesting moth collected on Paradise Key is the West Indian *Perigonia lusca interrupta* Walker (pl. 47, fig. 1),

a variety of what may be called in English the "purblind hawk-moth." It is of a reddish brown color, with the hind wings banded with a deep orange. Like many other Sphingidæ it feeds upon the nectar of flowers, about which it hovers like a humming bird, and thrusting its long proboscis far down into their corolla tubes. Among the day-flying wasp-moths are the *Syntomeida ipomoeae* Harris, which frequents morning-glories, a handsome species with orange-and-black banded abdomen and black wings spotted with white (pl. 44, fig. 5); and the closely allied polka-dot wasp-moth, *Syntomeida epilais* Walker (pl. 44, fig. 4), with the abdomen tipped with bright orange-red and with black wings and thorax spotted with white. Another wasp-moth of the park is the little *Didasys belae* Grote (pl. 47, fig. 4), with orange-tufted abdomen and transparent windows in its dainty wings. This exquisite insect is essentially Floridian, and is the only species referred to the genus Didasys.

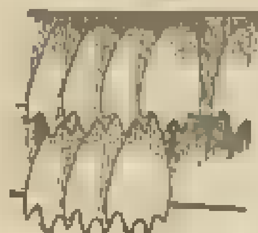

FIG. 21.—SCALES ON THE WING OF A BUTTERFLY, *Papilio* sp., 50 TIMES NAT. SIZE.

Of much wider distribution is the beautiful little tiger moth, most appropriately named by Linnæus *Utetheisa bella* (pl. 47, fig. 5). It has rose-colored hind wings bordered with black and orange red fore wings crossed by white bands dotted with black. Another interesting moth, belonging to the Noctuidæ, which fly by night, is *Xanthopastis timais* Cramer (pl. 45, figs. 1 and 2), the fore wings of which are a delicate rose color mottled with black and yellow, the hind wings of a silky mouse color, the thorax densely covered with erect black fur, the hairs of which as seen under the lens terminate in minute white club-shaped tips, and the abdomen clothed with black hairs. Its gaily banded larvæ, according to Doctor Dyar, feed upon "a species of lily." Specimens were collected by Mr. Thomas E. Snyder on Paradise Key where the adult insects have the peculiar habit of resting during the daytime on the trunks of royal palms, usually high above the tops of the other trees of the hammock. They are most abundant below the bushy fruiting spadices of the palms, and from a distance look like dark specks against the smooth, whitish, columnar trunks.

FIG. 22.—CASE OF LOG CABIN MOTH, *Oiketicus abbotii*, IN WHICH THE WINGLESS FEMALE SPENDS HER ENTIRE LIFE. HALF. NAT. SIZE.

Last of all must be mentioned little "log-cabin worm," *Oiketicus abboti* Grote, which constructs a case of sticks like a miniature crib (fig. 22). It is an obscurely colored little moth, related to our com-

mon bagworm (*Thoridopteryx ephemeraeformis*). The larvæ are sheathed in these little baskets, and the female, who is wingless throughout her life, never emerges, but deposits her eggs in the larval skin which lines the basket in which she has developed.

BUTTERFLIES.

Three of the butterflies of Royal Palm State Park may be designated the regal group: the "monarch," *Anosia plexippus* L. (pl. 48, fig. 2); the "queen," *Anosia berenice* Cramer (pl. 48, fig. 1); and the viceroy of Florida, *Basilarchia floridensis* Streck. (Pl. 48, fig. 3.) Of these the first two are closely related, but the last belongs to a distinct genus, though resembling in general appearance the monarch. Both the monarch and the queen are said to be avoided by birds, predacious insects, and other insectivorous animals on account of the ill-tasting, acrid, juices secreted by them, and it is believed by many naturalists that the viceroy imitates its royal companions, or rather has gradually become modified so as to resemble them, owing to the protection which this resemblance assures it. The male of the monarch is distinguished from the female by a black scent pouch on each of the hind wings. It feeds upon milkweeds (Asclepiadaceae) and is widely distributed over the globe. The Florida viceroy resembles the more northerly *Basilarchia archippus*, but is darker colored and somewhat larger than that species. Its caterpillar, which has prominent tubercules on the back, is found upon willows (*Salix amphibia*).

ZEBRA BUTTERFLY.

The most interesting and foreign-looking of all the butterflies in the park is the yellow and black banded *Heliconius charitonius* L. (pl. 47, fig. 2), belonging to a tropical family, of which it is the only representative in the United States. Special attention has been called to this group by the naturalists, Alfred Russel Wallace and Thomas Belt, in connection with the phenomenon of mimicry. The Heliconii are said to be avoided by insect-eating birds and other animals. They are protected, according to Wallace, by their unpleasant, strong, pungent taste. Belt noticed that certain other butterflies of a distinct family, and even certain species of moths resembling them very closely, shared their immunity from attack. In "The Naturalist in Nicaragua" he calls attention to this fact. He tells how he watched certain insectivorous birds feed their young with various kinds of insects including butterflies, but never in a single instance did he see them bring a Heliconius to their nest, though Heliconii were abundant in the locality where the observations were made. He tried to feed Heliconii to a captive monkey, who greedily ate beetles

and other butterflies, but the monkey could not be induced to eat them. When a Heliconius was given him the monkey would take it politely and sometimes smell it, but he would invariably drop it after holding it in his hand for a few minutes.[1] The butterflies and moths resembling them were also avoided; and the same was true of certain harmless insects resembling species provided with stings. The caterpillar of the Zebra butterfly feeds on the little passion flower (*Passiflora suberosa*), which is quite common in the park. It is interesting to note that both the butterfly and this host plant occur in Cuba and the Lesser Antilles. In Florida the species ranges from the region of Indian River and the headwaters of the St. Johns to Cape Sable. It also occurs in Mexico and ranges southward through the lowlands of Central America.

THE METAL-MARKS.

Calephelis caenius L., the "little metal-mark," is a very small butterfly belonging to the family Lemoniidae, and the subfamily Erycininae. It is of a reddish brown color on the upper side, brighter red on the under side. On both the upper and the under sides the wings are profusely spotted with small steely blue metallic markings, arranged in more or less transverse series, especially on the outer margin. Expanse, 0.75 inch. Its life history is unknown. This species is common in Florida, and ranges thence northward to Virginia and westward to Texas.[2]

ZAMIA BUTTERFLY.

The remarkable little "coontie" butterfly of the pinelands, *Eumaeus atala* Poey (pl. 45, fig. 8), belongs to the family which includes the little "blues" (Lycaenidae), but it is larger than most of its members. On Paradise Key it is only an occasional visitor, but it occurs on Palma-vista, in the northeast corner of the park, where its food plant, *Zamia floridana*, grows.[3] According to Holland its early stages await description, but Mr. E. A. Schwarz, of the United States National Museum, has given an account of its life history with excellent illustrations. The butterfly, which also occurs in Cuba, is conspicuous, not only on account of its coloration, but also for its abundance. The larva is of a brilliant red color, with tufted protuberances on every segment. The butterfly lays its cream-colored eggs, resembling microscopic, depressed, spineless sea-urchin shells, on the under side of the leaflets and along the midrib, or rachis of the leaves while they are still young and tender. In about

[1] See Belt, Thomas. The Naturalist in Nicaragua, p. 316. 1874.
[2] See Holland. The Butterfly Book, p. 232, pl. 28, fig. 16. 1898.
[3] See illustrations of this plant, pls. 31 and 32.

10 days the eggs hatch. Two weeks later the larvæ are full grown and assume the pupa state, which lasts 9 or 10 days before the perfect insect emerges.[1]

On plate 45, figure 9, is shown the closely allied *Eumaeus minyas*, which ranges from Texas to Brazil, and which in all probability passes its early stages on Cycadaceous plants related to Zamia.

THE NYMPHS.

Among the other butterflies of the park belonging to the subfamily Nymphalinae (which includes the Basilarchia described above) are the passion flower fritillary, *Dione* (*Agraulis vanillae*) L. (pl. 49, fig. 1), tawny and black above, with a few white dots, and beautifully spotted beneath with silver; the handsome peacock butterfly, or "buckeye," *Junonia coenia* Hübner (pl. 47, fig. 7), which is said to be very pugnacious toward other species; the white peacock, *Anartia jatrophae* L. (pl. 47, fig. 6), a faded-looking tropical species whose early stages have not yet been described; the dingy peacock, *Eunica tatila* (pl. 47, fig. 3), a dark-colored butterfly, with white spots and metallic, blue reflections on the upper surface of the wings and rows of many little eyes dimly visible on the under surface; and the portia, *Anaea* (*Pyrrhanaea*) *portia* Fabr. (pl. 49, fig. 3), a handsome species essentially tropical in its distribution, of a rich garnet color above and laced with yellow on the under surface of its fore wings.

THE SULPHURS.

Those found in the park include the cloudless sulphur, *Catopsilia eubule* L. (pl. 49, fig. 2 and fig. 5), the large orange sulphur, *Catopsilia agarithe maxima* Neum. (pl. 49, fig. 4), which pass their early stages on cassia plants, and the little cassia sulphur, *Eurema* (*Terias*) *euterpe* Menetries (pl. 50, fig. 3). In addition to these may be mentioned the "Florida white," *Tachyris ilaire* Godart, the male of which has the hind wings on the under side of a very pale saffron color.

SWALLOW TAILS.

Among the swallowtails of the park is the magnificent *Papilio cresphontes* Cramer (pl. 50, fig. 2), the larva of which is usually called "orange-puppy" from its habit of feeding on citrus trees. Here it is found on the native wild lime, *Zanthoxylum Fagara*, a shrub or small tree botanically allied to Citrus, which has its foliage dotted with minute aromatic oil glands. The butterfly has brown wings banded with bright yellow, and closely resembles *Papilio*

[1] See Schwarz, E. A., Notes on *Eumaeus atala*, Insect Life, vol. 1, pp. 37–40. 1888.

thoas of southern Texas. In southern Florida great damage is sometimes done to the orange groves by the caterpillar. Another beautiful swallowtail is *Papilio palamedes* Drury (pl. 50, fig. 4), which in its early stages feeds on the leaves of various bay trees; not only on those of the swamp bay (*Tamala pubescens*), belonging to the Laurel family, but also on the foliage of the sweet bay (*Magnolia glauca*), which belongs to a very distinct family, but is aromatically fragrant like the laurels, or true bays.

Among the more sober-colored butterflies of the park are two so-called skippers, *Pamphila ocola* (*Prenes ocola*, Edwards), the life history of which has not been studied, and the swallow-tailed *Eudamus proteus* L. (pl. 50, fig. 1), the caterpillar of which feeds upon leguminosæ and makes a rude nest for itself by drawing the edges of leaves together with strands of silk after having cut slits in them. By the farmers it is appropriately called the bean leaf roller, and is regarded as a pest.

ANTS, WASPS, AND BEES.

The hymenoptera of Paradise Key were kindly identified for the writer by Mr. J. C. Crawford and Mr. S. A. Rohwer, of the United States National Museum, and Mr. H. L. Viereck, of the United States Biological Survey. Several of the most remarkable species are shown on plate 51.

ANTS.

The carpenter ant, *Camponotus* (*Myrmothrix*) *abdominalis*, represented in Paradise Key by the subspecies *floridanus* (pl. 51, fig. 2), must have come into Florida from the West Indies.[1] Like its nearest relatives, this ant makes tunnels or galleries in dead wood, and, like other true Formicidæ, its colonies consist of several distinct forms or castes; in addition to males, females, and workers, a large-headed caste usually called soldiers. As in the termites, females and males are winged, while the workers and soldiers are wingless. Comstock, who has studied the habits of the closely allied carpenter ant (*Camponotus pennsylvanicus*) of the eastern United States, describes the nuptial flight of the males and females. Very soon after the honeymoon the male dies; and the pregnant female, tearing off her own wings, for which she has no further use, proceeds to form a new colony very much after the manner of the bumblebees and social wasps. On many occasions Comstock found a female carpenter ant in a small cleared space beneath the bark of a dead tree or log, either alone or accompanied by eggs, larvæ, or small workers. Usually the females are styled "queens," but this name is hardly applicable to

[1] Wheeler, W. M., Ants, Their Structure, Development, and Behavior, p. 151.

those of ants. They are simply the mothers of their colonies. Several of them may live together in perfect harmony, unlike the jealous queen bee, who suffers no rival to her throne. But, if not really a queen, the mother ant is treated with queenly consideration by her children, who feed her, care for her eggs as soon as she lays them, and administer to all her wants.[1]

In addition to the species just described is a form of the widely spread *Camponotus maculatus*, which occurs on every continent and many islands and is divided into a number of well-marked varieties, or subspecies; a small stinging ant (*Pseudomyrma gracilis?*) closely allied to tropical American species inhabiting the hollow thorns of bull-horn Acacias; and the tiny, yellowish "Pharaoh's ant" (*Monomorium pharaonis*) which is so often a pest on board ship as well as in houses.

FIG. 23.—NESTS OF POTTER WASP, *Eumenes sp.*, OFTEN INVADED BY PARASITIC JEWEL WASPS, *Chrysis spp.* HALF NAT. SIZE.

POTTER WASPS AND JEWEL WASPS.

On the framework of the lodge veranda, outside the copper gauze, there were a number of little wasp nests resembling miniature ollas, or earthenware decanters. These were the work of a slender-waisted, black and yellow insect belonging to the genus Eumenes. Some of the nests were grouped in vertical rows (fig. 23), while others were solitary, closely resembling similar nests found on the stems of marsh plants in the adjoining Everglades (pl. 51, fig. 11). On opening some of the little ollas the remains of insect larvæ with which they had been stored were found, but accompanying these, instead of a baby Eumenes, a beautiful, little, jewellike wasp (*Chrysis sp.*) was found; in some cases of a brilliant sapphire luster, in others an emerald green (pl. 51, fig. 12). Specimens of these little insects caught near the nests, immediately rolled themselves up like miniature armadillos. Under the lens their brillant surface was found to be minutely and regularly pitted, each concave pit reflecting a brightly colored light, causing the insect to shine with exquisite luster. On plate 52 three specimens from Paradise Key are shown, enlarged 6 diameters. One of them is rolled up for defense as described. The abdomen is somewhat concave on the under side,

FIG. 24.—POTTER WASP, *Eumenes sp.*, WHICH BUILDS ITS NESTS ON THE VERANDA OF THE PARK LODGE. FROM SPECIMENS COLLECTED BY C. A. MOSIER. NAT. SIZE.

[1] See Comstock, J. H., Manual for the Study of Insects, 7th ed., pp. 634–636. 1907.

and is bent under the thorax when the insect rolls itself up. In its parasitic habits it resembles the ichneumons. On discovering the nest of a potter wasp it waits until the potter (fig. 24) is absent; then the little rascal, not caring to make a nest of its own, deposits its egg in the potter's nest. Sometimes it is surprised in the act, and the indignant potter attacks it, but it rolls itself up into a ball, relying upon its metallic armor for protection, and the only damage it can suffer is the loss of its projecting wings. St. Fargeau observed a bee, who had surprised one of these little robbers *flagrante delicto*, bite off its four wings; but she did not thereby save her young, for as soon as she was gone the wingless Chrysis crawled into the nest and deposited its eggs. It is on account of this habit that the chrysids are called cuckoo flies. The Germans call them *goldwespen* (gold wasps), for some of the European species have a golden luster. To the writer the name "jewel wasps" seems most appropriate. At least two species were collected in Royal Palm State Park, one belonging to the section Tetrachrysis, and the other, identified by Mr. S. A. Rohwer as *Chrysis parvula* (pl. 51, fig. 13), belonging to the section Trichrysis. On being shown one of the clay nests above described, Mr. John Peabody Harrington of the Bureau of American Ethnology at once recognized its resemblance in form to certain vessels of earthenware used by the Diegueno Indians of southern California as receptacles for the ashes of their cremated dead.

FIG. 25.—SOLITARY WASP, *Odynerus quadrisectus*, WHICH CONSTRUCTS MUD CELLS IN CANES AND HOLLOW TUBES. NAT. SIZE.

OTHER PARASITIC WASPS.

Closely allied to the potter wasps, but somewhat less elegant in form, are the solitary wasps of the genus Odynerus, which construct cells of mud in tubular cavities and store them with small caterpillars for their own larvæ to feed upon. On the island of Guam a certain species of this genus was very abundant, filling with its cells empty cartridge cases, rolled-up magazines or newspapers left lying about, the hollow internodes of bamboos, and even gun barrels. In each cell examined the writer found a small, green caterpillar, which had been stupefied but not killed by the insect's sting. The larvæ of the Odynerus in eating their animal food are much more active than those of pollen-feeding insects, continuing to turn their heads from side to side and living for some time after having been taken from their cells.[1] One of the species collected on Paradise Key was identified by Rohwer as *Odynerus quadrisectus* (fig. 25), a

[1] See Safford, W. E., The Useful Plants of the Island of Guam. Contr. from the National Herbarium, 9: 92. 1905.

pretty insect, somewhat like a yellowjacket, marked with four transverse yellow bands.

Campsomeris quadrimaculatus, the largest wasp of the park (pl. 51, fig. 7), takes its name from four bright yellow spots on its abdomen. This insect makes no nest, but burrows in the earth in search of grubs of beetles and other larvæ, in which it deposits its eggs. Contrasting with it in size is a square-headed little solitary wasp, *Hypocrabo decemmaculatus* (pl. 51, fig. 3), which stores its cells with small insects. Smaller than this are *Pristaulacus floridanus* (pl. 51, fig. 5), belonging to the ensign flies (Evaniidae), and a certain unidentified Braconid belonging to the genus Heterospilus, many individuals of which were found in the burrow of a borer.

HORNETS AND MUD DAUBERS.

A collection of Hymenoptera received from Mr. C. A. Mosier in March, 1918, included several hornets, mud daubers, and solitary wasps, kindly determined for the writer by Mr. H. L. Viereck. Among the hornets, or social wasps, were *Polistes rubiginosus*, of a reddish-brown color, which constructs unprotected nests resembling honeycomb in sheltered places, and *Polistes annularis*, somewhat smaller and darker colored, which ranges as far north as New Jersey. Among the mud daubers were *Sceliphron cementarius*, a widely distributed species with very slender-pediceled abdomen, and legs variegated with yellow; the dark, steel-blue *Chalybion coeruleum;* the "thread waist" mud wasp, *Sphex vulgaris*, with the upper part of the abdomen adjoining the threadlike pedicel orange-colored; and the little slender *Trypoxylon collinum*, devoid of yellow bands on the abdomen, many of whose close allies store their cells with small spiders or insects. In addition to these there was a rare little solitary wasp, *Zethus* (*Didymogastra*) *poeyi*, with its abdomen separated from the thorax by a fusiform or pear-shaped peduncle, and with narrow wings directed backward but not overlapping.

BEES AND THEIR ALLIES.

Among the bees collected on Paradise Key the following have been identified by Mr. Crawford: *Bombus pennsylvanicus*, a widely spread bumblebee (pl. 51, figs. 8, 9, 10); *Xylocopa micans* Fabr., a carpenter bee, which excavates galleries in dry wood (pl. 51, fig. 1); several leaf cutters, including the rare *Megachile pollicaris* Say (pl. 51, fig. 4); a parasitic cuckoo bee (Coelioxys); and a metallic, green jewel bee (*Augochlora*) which digs burrows in the ground.

Perhaps the most interesting of all these are the leaf cutters belonging to the genus Megachile (pl. 51, fig. 4). These are the insects which cut circular disks from leaves with which to line their

nests. Some of them are carpenters as well as leaf cutters, and excavate tunnels in wood before cutting the disks. The lined tube, usually rounded at the bottom, is partially filled with a paste of pollen and nectar, upon which the egg is deposited and the hole is then stopped up with circular leaf disks a little greater in diameter than the tube itself.[1] Like the provident potter wasps the leaf cutter bees also have their enemies; the nests so carefully prepared for their tender offspring are infested by cuckoo bees, belonging to the genus Coelioxys. This genus is represented in the author's collection by three specimens of *Coelioxys dolichos* Fox (pl. 51, fig. 6), collected on Paradise Key by Mr. Mosier.

FLIES.

The Diptera of Paradise Key include many groups zoologically related but with very diverse habits: mosquitoes; horseflies and deer flies, which not only attack animals but which even pursue automobiles for miles; robber flies, which catch their insect prey on the wing; flower flies, which feed on nectar and pollen; parasitic tachina flies, which lay their eggs on living insects; and carrion-eating flesh flies.

MOSQUITOES.

Aedes niger, the most common mosquito in the vicinity of the park is congeneric with the yellow-fever mosquito (*Aedes calopus*), but it has never been known to communicate a malignant disease. Its bite, though painful, is not nearly so severe as that of certain other species, and is not followed by unpleasant consequences. Volatile aromatic oils rubbed on the face, neck, and other exposed parts yield temporary protection from their attacks, and campers resort to the use of smudges for smoking them out of their tents.[2] The writer has already referred to the part played by dragon flies in the destruction of mosquitoes. Their aquatic larvæ furnish food for young fishes. Some of the species undoubtedly deposit their eggs in the water reservoirs of the epiphytic Bromeliads already described.

A popular account of the mosquitoes of Florida was published by Dr. Hiram Byrd, of the Florida State Board of Health, in the Medical News, June 10, 1905.

Among the mosquitoes from Royal Palm State Park determined by Doctor Dyar are *Wyeomyia antoinetta*, *W. mitchelli*, *Culex similis*, *C. peccator*, *Psorophora posticatus*, *P. floridensis*, *Aedes niger*, already mentioned, *A. infirmatus*, *A. sollicitans*, *Anopheles quadrimaculatus*, and *A. crucians*.

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[1] See Comstock, Manual for the Study of Insects, 7th ed., pp. 667–668. 1907.
[2] See Howard, L. O., U. S. Department of Agr. Farmers' Bull. 444. 1913.

For a systematic treatment of the group the reader is referred to the monumental work of Howard, Dyar, and Knab, "Monograph of the Mosquitoes of North and Central America and the West Indies," published by the Carnegie Institution of Washington, 1912 to 1917.

HORSEFLIES AND DEER FLIES.

While sitting on the lodge veranda our attention was frequently attracted by passing teams, the horses of which were attended by boys whose business it was to protect them from the attacks of insects; from mosquitoes, I at first thought, but from horseflies, I was told by Mr. Mosier. These flies are very annoying in southern Florida, not only to horses and other animals but to human beings as well. The largest of them all, a magnificent emerald-eyed insect, called by the Seminole Indians *chillee-o-deno*, is *Tabanus americanus* (pl. 45, fig. 3), the interesting nuptial flight of which has been recently described by Mr. Thomas E. Snyder, of the Office of Forest Entomology, United States Department of Agriculture.[1]

Among the other horseflies collected on Paradise Key by Mr. Snyder were *Tabanus trijunctus* Walker (pl. 53, fig. 2), *T. melanocerus* Wied., and *T. lineola* Fabr. Mr. Snyder found *T. trijunctus* very common from Hobe Sound to Paradise Key, often flying after automobiles and railway trains; so annoying is it to painters and other workmen that they have to protect themselves from it by means of portable smudges. Of *T. lineola* he says that it is such a pest in some localities that horses and mules have to be protected from it by gunny sacking with holes cut for the eyes. Thus grotesquely clothed they suggest the mounts of the Ku-Klux Klan. Among the deer flies, belonging to the genus Chrysops, much smaller and more brightly colored than the horseflies, but equally bloodthirsty, were two species, *Chrysops flavidus* (pl. 53, fig. 6) and *Chrysops plangens*, both of which are pretty widely distributed in the eastern United States. Their predacious larvæ, like those of Tabanus, live in water, in mud, or under stones, and feed upon water snails and soft-bodied insects.

OTHER DIPTERA FROM PARADISE KEY.

The soldier fly, *Hermatica illucens*, shown on plate 53, figure 9, lays its eggs in decaying organic matter. Among the Syrphidae, or flower flies, are the little *Ocyptamus fuscipennis* (pl. 53, fig. 1), *Eristalus vinctorum* (pl. 53, fig. 4), *Eristalus albifrons*, and *Meromacrus acutus*. These insects, called "hover flies" by the English, from their habit of hovering over flowers, feed on nectar and pollen. The larvæ

[1] See Snyder, Thomas E., Notes on horseflies as a pest in southern Florida. Proc. Entomological Soc. of Wash., 18: 208. 1916.

of some of the species have a long, caudal appendage and are hence called "rat-tailed maggots." One peculiar larva collected by Mr. Mosier, the park warden, was referred to the genus Microdon by Mr. C. T. Greene, who says that it differs from all allied larvæ in the collections of the Museum in the peculiar form of its spiracles.

The wasplike Midas fly, *Mydas clavatus* (pl. 53, fig. 5), which has a golden band across its abdomen, takes its generic name from the Phrygian king Midas, concerning whom the legend relates that everything he touched was transformed to gold. Like the robber flies (Asilidae) it catches and devours other flying insects. Its larva is also carnivorous, subsisting mainly on the grubs of beetles. *Archytas hystrix* (pl. 53, fig. 8) is a stout tachina fly, somewhat resembling a bluebottle, but with a glossy brown body set with short stiff hairs. It lays its eggs on living insects, principally on caterpillars. Last of all may be mentioned the terrible little screw-worm fly, *Chrysomyia macellaria* (pl. 53, fig. 7), with a reddish brown face, a steel blue thorax, and a short, broad, black abdomen, which lays its eggs in wounds, or in the nostrils of living animals. It has even been known to deposit its eggs in the nostrils of human beings sleeping out of doors, but this is a rare occurrence. The eggs soon hatch, and the larvæ, called "screw worms," eat away the flesh of the inner nose and pharynx, causing intense pain and sometimes death. This little fly causes little trouble in the Southeastern States, but in the Southwest it is a serious pest, infesting cattle, hogs, and other domestic animals. Some times it lays its eggs in the navels of new-born calves.[1]

FISHES.

The Everglade fishes in the vicinity of Royal Palm State Park have never been systematically collected. The highway from the park to Cape Sable now under construction has a canal bordering it, formed by the removal of material for the roadbed. The digging is accomplished by a dredge, the parts of which were brought from Miami on trucks and assembled in the canal. This canal is already well stocked with fishes which can be easily observed from the road. The fish fauna should be studied before the canal reaches the ocean; for many marine fishes will undoubtedly make their way up the canal and will destroy existing conditions, which may possibly lead to the destruction of some of the existing species. Among them are the alligator gar and mudfish, allied to the ancient ganoids; a bullhead catfish; three or four minnows, or shiners (Cyprinidae); rare Everglade killifishes, some of which bring forth their young alive; sunfishes, or so-called breams; and the widely distributed, big-mouth bass, or "trout."

[1] See Farmers' Bull., 857, U. S. Dept. Agr., 1917.

THE ALLIGATOR GAR, LEPISOSTEUS TRISTOECHUS.

This is a voracious fish remarkable for its armor plating of enameled rhomboid scales. The accompanying illustration (fig. 26) was made from a field sketch by Master Stewart Loveland, of Homestead, of a specimen 25 inches long, weighing 3 pounds, speared by him near Paradise Key. This species sometimes reaches enormous dimensions. A specimen in the State Museum at Springfield, Illinois, is 7 feet 2 inches long. It is widely distributed in streams flowing into the Gulf of Mexico, and also occurs in the fresh waters of Cuba. Many stories have been told of its ferocious nature and uncanny habits; it takes the place of the predacious sharks in the fresh waters of our country. Although it does not rank high as a food fish, it is sold in the markets of Tampico, Mexico, and other Gulf ports.

The family to which the alligator gar belongs (Lepisosteidae) is essentially American, like the mudfish (Amia) to be described below. Fossil species of the genus, however, are found in the Eocene of Europe as well as in that of America.

FIG. 26.—ALLIGATOR GAR, *Lepisosteus tristoechus*, FROM A FIELD SKETCH BY STEWART LOVELAND OF SPECIMEN SPEARED BY HIM NEAR PARADISE KEY. ONE-SIXTH NAT. SIZE.

THE MUDFISH, OR DOGFISH, AMIA CALVA.

This species is found in swamps, lakes, and rivers bordering the Gulf of Mexico, extending up the Mississippi and its tributaries as far north as the Great Lake region. It is especially abundant in swamps and sluggish waters abounding in aquatic vegetation, preferring rather shallow water, and feeding principally at night. Gamy and voracious, it is "one of the hardest fighters that ever took the hook." It frequently comes to the surface to breathe, especially in stagnant water; and can be kept in a rain barrel for a long time without change of water. It is said to survive periods of drought by burying itself in the mud. The male builds the nest and guards it after the eggs are laid; he is a good father, even accompanying and protecting the schools of young after they leave the nest. It is not highly esteemed for food, but is often eaten in the South. The mudfish is chiefly interesting on account of its close resemblance to ancient types of ganoid fishes. It is the only surviving relative

of a once large family represented by numerous fossils from the Jurassic of France and Bavaria and the Eocene of Europe and North America.

OTHER FISHES OF THE EVERGLADES.

The catfish caught in the slough near Paradise Key is in all probability *Ameiurus nebulosus*, a species which has been collected in Little River, a short distance north of Miami. Among the Cyprinidae are the golden shiner, *Abramis roseus*, a tiny species, only 2½ inches long when fully grown, which takes its name from the rosy color of the fins, iris, and snout of the male. Among the killifishes (Poeciliidae) of southern Florida, which are to be expected from the vicinity of Royal Palm State Park, are several species of Fundulus, some of which do not exceed 2 inches in length when fully grown; the viviparous "top minnow," *Gambusia affinis*, which lives mostly on surface insects; the "least fish," *Heterandria formosa*, abundant in swamps and ditches near Miami and Little River, the adult female of which is only an inch long, and the male three-quarters of an inch; *Jordanella floridae*, also common in the swamps of Florida; and perhaps *Mollienisia ongipinna*, the male of which is remarkable for his handsome dorsal fin. Among the sunfishes (Centrarchidae) which certainly occur in the Royal Palm State Park, are the so-called blue bream, or bluegill, *Lepomis incisor* (*Lepomis pallidus* Jordan), and *Lepomis holbrooki* (*Eupomotis holbrooki* Jord. and Everm.). A beautiful illustration in colors of the former is published in the Fishes of North Carolina, by Dr. Hugh M. Smith, United States Commissioner of Fisheries, who pays it the following tribute:

> This is the largest and finest of the sunfishes. It attains a length of 12 to 14 inches and a weight of a pound and a half, and when full grown is a magnificent species. As a game and food fish it stands high. * * * This fish has for many years been called *Lepomis pallidus* in the belief that Mitchill's name of *Labrus pallidus* applied to it; but a close examination of Mitchill's description shows that it could not have been intended for this species, and furthermore the bluegill is unknown in the locality from which the type of *pallidus* came. The earliest available name is *incisor* of Cuvier and Valenciennes.[1]

Drawings of both *Lepomis incisor* and *L. holbrooki* were made for the writer by Master Stewart Loveland of Homestead, who caught them in the slough near Paradise Key.

BIG-MOUTHED BASS, OR TROUT.

This species, known scientifically as *Micropterus salmoides*, is the largest and most important of the fresh-water basses, and is a fine

[1] See North Carolina Geological and Economic Survey, vol. 2, p. 242, pl. 9, 1907.

food and game fish. According to Dr. Hugh M. Smith, who figures it in the work above cited—

It inhabits more sluggish and warmer waters than the other species, and thrives under more extreme conditions of environment and temperature. * * * It reaches its maximum weight in Florida, where examples weighing as much as 20 to 25 pounds have been taken in lakes.

After describing its nesting habits and the solicitous care of the newly hatched young by the parents, Doctor Smith continues:

The food of the young fish consists of minute animals—crustacea, insects, etc. At a very early period, however, they begin to prey on their smaller brothers, and this cannibalism continues after they become adults. The larger fish are very voracious and aggressive feeders, taking all kinds of fish as well as small mammals, frogs, tadpoles, snakes, worms, insects, and also vegetable matter.[1]

FROGS AND TOADS.

In the forest of Paradise Key two little tree frogs abound; and the neighboring sloughs and marshes are inhabited by a beautiful, spotted leopard frog and a green bullfrog.

TREE FROGS.

While sitting on the screened veranda of the park lodge, besieged by clouds of mosquitoes, the attention of the writer was attracted by a number of diminutive tree frogs, some of them green, others brownish, on the outside of the copper-wire gauze. One of the smallest, whose body was scarcely bigger than a dime, made a sudden spring and caught a mosquito. Against the bright sky his little body was almost diaphanous and a dark speck could be seen in his stomach; it was the mosquito he had just swallowed. After another successful catch there were two specks, and continuing his good work the little creature soon had his stomach comfortably full. Then he folded his little arms close to his body and went to sleep. Closer examination showed that there were two species of these little frogs, the second distinguished from the one first noticed by lateral metallic bands. Alcoholic specimens were identified by Dr. Leonhard Stejneger as *Hyla squirrela* (fig. 27) and *Hyla cinerea*, respectively.

FIG. 27.—TREE FROG, *Hyla squirella*, WHICH WAGES INCESSANT WARFARE ON MOSQUITOES AND OFTEN NESTLES IN THE COROLLAS OF FLOWERS. NAT. SIZE.

In the woods these little creatures were commonly seen clinging to leaves from which they could scarcely be distinguished, and at Homestead, while awaiting transportation to the park, the writer

[1] See North Carolina Geological and Economic Survey, vol. 2, p. 247. 1907.

noticed a number of them on flowering Datura, in a funnel-shaped corolla of which one of them had established itself as a desirable station for securing his insect food.

MARSH FROGS.

The leopard frog of Royal Palm State Park, *Rana sphenocephala* Cope, regarded by Doctor Stejneger as a variety of our well-known *Rana pipiens*, is beautifully figured by Miss Dickerson in her Frog Book. To this species Miss Dickerson pays the following tribute:

> The southern leopard frog is perhaps the most beautiful frog in North America. It has not the delicate modest beauty of the wood frog, but it has distinction of form, richness of coloring, and intricacy of color patterns. It has not, like the wood frog, an expression indicating gentleness and tameness. Instead, a creature extremely alert and wild, possessing great powers of activity, is seen in the unusually large eyes and in the attentive pose of the slender body. * * * The male, *Rana sphenocephala*, has large vocal pouches, one at each side, above the arm. These frogs are wild and active. They leap long distances, and are difficult to catch. The species is evidently a very distinct one, not intergrading with *Rana pipiens*, but holding its own with the latter frog in the same localities in the southern part of the United States.[1]

The Florida bullfrog, *Rana grylio* Stejneger, is also described and figured by Miss Dickerson, who designates it as "a beautiful frog, very retiring and thoroughly aquatic in habit." It is usually of a vivid metallic green on the head and shoulders and olive on the posterior portion of its body, with a pointed head, bulging eyes, the ears of the male remarkably large and conspicuous, spheroid in shape, and of an orange-brown color with a green center, and the throat a bright yellow. It is probably this species which is common in the slough near Paradise Key, living among the dense aquatic vegetation among which it seeks refuge when disturbed. Miss Dickerson compares the sounds which it produces to "the grunting of a herd of pigs," thus differing from the familiar bass notes of the common bullfrog.[2]

REPTILES.

TURTLES.

Among the turtles of Royal Palm State Park is a large terrestrial box tortoise, a living specimen of which was received from the park warden. This was determined as *Terrapene major* (*Cistudo major* Agassiz), by Dr. Leonhard Stejneger, of the United States National Museum, to whom the writer is indebted for much information regarding the batrachians and reptiles of the region here considered.

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[1] See Dickerson, Mary C., The Frog Book, pp. 180–188. 1906.

[2] Dickerson, op. cit., 226 to 228, pls. 83 and 80.

An aquatic turtle, collected by Mr. Arthur H. Howell, proved to be *Pseudemys floridana*, belonging to the group of river turtles. In addition to these Mr. Mosier reports the following species from the park: A snapping turtle, a soft-shelled or leather-backed turtle, a small water turtle with conspicuous red markings beneath, and a large, hard-shelled, water turtle, which is very good to eat. The well-known gopher of Florida, *Gopherus polyphemus*, so common on sand dunes near the coast, does not occur in the park.

ALLIGATORS.

Alligator mississippiensis is not uncommon in the slough at the eastern entrance to the park. During the writer's visit its bellowing could be distinctly heard from the lodge, especially in the early morning. These huge animals are not at all dangerous, but will flee at the sight of a man and will not show fight unless brought to bay. Young alligators feed mostly on fishes, frogs, and insects; the older ones also catch waterfowl and unwary mammals which come within reach. They drown their prey by holding it under water, but in order to swallow it they must raise their head above the surface. Alligators' eggs, which are about as large as those of a hen, but oblong in shape, are eaten in many parts of the South. They are nutritious and are as good as turtles' eggs. The young when hatched are about 8 inches long. Though they do not appear to thrive in captivity when brought north, they develop rapidly in their native surroundings.

In addition to the alligator there is a true crocodile in southern Florida, but it does not occur near the park. This animal, called by zoologists *Crocodilus acutus*, is closely related to *C. vulgaris*, the man-eating crocodile of Africa which was worshipped by the ancient Egyptians and took part in their religious pageants and processions. It is easily distinguished from the alligator by its narrower head and pointed snout. Specimens 11 or 12 feet long are not rare, and it sometimes reaches the length of 14 feet. Its range extends from Lake Worth to Cape Sable. South of the United States it ranges from central Mexico to Ecuador and the West Indies. Though showing vicious propensities in captivity it is naturally timid in its wild state.

The sight of a child will send a 12-foot specimen rushing from its basking place for the water, and a man may even bathe with safety in rivers frequented by the species.[1]

LIZARDS.

Sharply contrasted with the giant saurian of the swamps are the little terrestial lizards commonly called skinks and chameleons. The

[1] See Ditmars, R. L., The Reptile Book, pp. 89–91. 1907.

Florida skink, *Plestiodon egregius*, is only 3½ or 4 inches when fully grown. Its body is cylindrical and slender, almost wormlike, with small, weak limbs. It is of an olive or reddish brown color with four, equidistant, longitudinal stripes margined with obscure dotted lines.

The so-called chameleon, *Anolis carolinensis*, takes its common name from its changing color. It is not related to the true chameleons of the Old World so often celebrated in fabulous stories, but belongs to the iguana family and bears a superficial resemblance to a miniature alligator. Specimens of this little animal were seen on the screened veranda of the park lodge running about with ease upon the vertical walls and even on the ceiling, to which it adhered by means of its peculiar, padded toes, while it was busily engaged in catching mosquitoes and other insects. In its habits it reminded the writer of the geckos so common in dwellings on the island of Guam. Mr. Snyder states that they are very active in the woods when the termites swarm, devouring them in great quantities. Sometimes it assumes a dull, brown color, at other times a vivid green. The males have a throat pouch which they inflate, while uttering a peculiar sound very much like that of a baby alligator, and they have a way of nodding their head that is odd and comical. Unlike the little tree frogs frequenting the veranda, these little animals were very timid, and quickly escaped when attempts were made to capture them.

SNAKES.

Among the harmless snakes of the park are two garter snakes; *Thamnophis sirtalis*, with three, yellow, longitudinal stripes and the more slender *Thamnophis sackeni*, with two, long, lateral stripes and the beginning of a short median stripe on the back of the neck. Both of these species are semiaquatic, subsisting upon frogs and fishes as well as earthworms and toads; and they bring forth their young alive. Two water snakes are found in the sloughs and pools of the Everglades: the "spotted belly" *Natrix fasciata*, sometimes erroneously called a moccasin, but easily distinguished from the poisonous water moccasin by its yellowish white abdomen spotted with bright red blotches and clouded spots of black and gray; and the so-called green water snake, *Natrix cyclopion*, with an unspotted, yellowish abdomen and yellow lips. Both of these species are harmless, but they simulate poisonous species by flattening themselves out and assuming a threatening attitude when cornered.

Among the racers or black snakes is the well-known gopher snake, *Drymarchon corais couperi*, a variety of the large tropical American *D. corais*, sometimes 8 or 10 feet long, with a highly polished, blue-black body, which has given it the name of indigo snake in certain localities. It has a gentle disposition and often lives about houses

in a semidomesticated state, subsisting principally on rats and mice. Children sometimes pick it up, and it seems to enjoy being petted. A fine, large specimen of this snake greeted the writer at the door of the lodge, when he alighted from the automobile which conveyed him to the park. The park warden gave a vivid description of the mating of a pair, in which both the male and female strutted in front of each other, as though trying to show off to the best advantage. Closely allied to this species is the black racer, *Coluber constrictor*, which does not kill its prey by squeezing, as commonly believed, but is a constrictor only in name. Both of these snakes are oviparous, the shell of the egg of the latter being white and tough and sprinkled with grains resembling coarse salt. Both species have the reputation of charming birds and small rodents, but this power is quite imaginary. The two species are easily distinguished, the gopher snake by its glossy body and reddish brown throat, chin, and upper lip plates, and the black racer by its dull slaty luster and milky white throat and chin. The closely allied coachwhip, or whip snake, *Coluber flagellum*, differs from the two preceding species in having a nasty, irritable disposition, and will not submit to being handled. Its body is slender, of a black or brown color above, becoming lighter toward the tail, and the under surface white, with the plates of the throat clouded along the edges. It is very swift, often climbing trees in quest of eggs and young birds, but it can not be called arboreal.[1]

The green tree snake, or magnolia snake, *Opheodrys aestivus* (*Cyclophis aestivus*), is a gentle creature of a uniform leaf-green above and bright yellow beneath. It lives among the branches of bushes and low trees, feeding upon grasshoppers, crickets, the larvæ of insects, and, according to Mr. Mosier, on small tree toads. In describing the vegetation of southern Florida hammocks, Dr. Small refers to this species as follows:

> Orchids, air plants, and ferns completely clothe the limbs of the larger trees. However, plants do not have a monopoly of the trees. There are also epiphytic lizards and epiphytic snakes. There is everywhere present a beautiful green snake. It inhabits the hammocks and it is especially abundant in those of the Everglades. It lies outstretched on the branches of shrubs and trees and glides along the branches from one tree to another with surprising ease. One has usually to be careful to look before laying hold of the limb of a tree for support, or he may grasp something of quite different consistency from that of wood. One reason why this little creature is so much at ease among shrubbery is the peculiar nature of its scales, each of which is distinctly keeled, so that the general surface of the body is roughened and thus able to hold on more securely to the branches along which it glides.

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[1] See Ditmars, R. L., The Reptile Book, pp. 250–257. 1907.

HOG-NOSE, OR PUFF ADDER, *Heterodon contortrix* (*H. platyrhinus*).

Concerning this species, which he kept in captivity, Dr. Hiram Byrd writes as follows:

> Among the snakes of my pit the puff adder acts the part of clown. He is all bluff. If you come upon him suddenly he spreads his hood like a cobra, and tries to frighten you with his looks. Failing, he blows like a rattlesnake. If you are still undaunted, he takes to flight. If you do not permit that, and proceed to tease him, he then resorts to camouflage, which is to turn over on his back and, possumlike, play dead. He will even try to creep away on his back. I can't imagine the rattlesnake associating with the puff adder on terms of social equality.[1]

This snake is easily recognized by its turned-up nose and its mottled brown body.

THE COTTONMOUTH, OR WATER MOCCASIN, *Ancistrodon piscivorus*.

This species, so much dreaded by travelers in the Everglades, is closely allied to our copperhead, *Ancistrodon mokasen* (*A. contortrix*), which is sometimes called the highland moccasin. The top of its head is very dark, usually black, the chin and lower lips yellow, with three dark bars on the lip plates on each side of the mouth, and the abdomen is yellow blotched with dark brown or black, while the under portion of the tail is black. This coloration of the abdomen serves to distinguish it from its harmless associates, with which it is sometimes confused, *Natrix fasciata*, which has a yellowish white abdomen spotted with red and black; and *Natrix cyclopion*, which has a uniform yellowish abdomen. When surprised it has the habit of opening its jaws widely, disclosing its white mouth parts, from which it takes its name of cottonmouth. In addition to fish, frogs, and other snakes, it feeds upon birds and small animals. It brings forth its young alive, usually seven to twelve.

RATTLESNAKES.

The pigmy rattlesnake, or ground rattler, *Sistrurus miliarius*, may be recognized at once by its small size and minute rattle. The adults scarcely reach a length of 18 inches. Their warning rattle is so faint that it can be heard from the distance of only a few feet. The diamond-back, *Crotalus adamanteus*, is the largest of all the rattlesnakes, sometimes reaching a length of 6 to 8 feet. It is recognized at once by its rattle and its broad, flat head and distinctly narrowed neck. It is of an olive or grayish green color with a longitudinal chain of large, diamond-shaped patches outlined with bright yellow. With its long fangs and large poison glands it may be regarded as one of the most deadly poisonous snakes in the world. Doctor Byrd has made

[1] Byrd, Hiram, Letter to writer dated Homestead, Fla., Nov. 15, 1917.

some interesting observations on the life history of the species, from their earliest stages to maturity. He was bitten on the finger by a specimen 12 days old while trying to feed it. He stopped circulation immediately by the use of an improvised tourniquet, and though experiencing certain odd sensations of chilliness, escaped serious injury. Unlike the solicitous mudfishes and basses of the neighboring Everglades, who protect their young for some time after they are hatched, rattlesnakes let their little ones shift for themselves as soon as they come into the world. Dr. Byrd could discover no evidence of parental affection among them; yet in admiration of their innate dignity, courage, and their disdain to strike without warning, he composed an ode in their honor, which ends with the following stanzas:

> Yet all thy virtues wrest from man no lays,
> Who sings of war and love, of bird and bee,
> And e'en of rusty toad, but not of thee.
> To thee he yields but hate or fear, not praise.
>
> Indifferent thou to hatred, fear, or wrong,
> Content in jungle drear to seek thy food
> And make thy home and launch thy royal brood
> In solitude.—I grudge thee not a song.

BIRDS.

The bird fauna of southern Florida is especially rich, not only on account of the mild climate, favorable to many subtropical species, but also because Florida is a highway for migratory species which spend their winters in the West Indies. Mrs. Kirk Munroe, president of the Cocoanut Grove Audubon Society, and Mrs. Hiram Byrd, who resides at Princeton, not far from Paradise Key, have interested themselves in observing the birds of this vicinity and making a census of its bird fauna. It is impossible within the scope of this paper to give a detailed account of the birds, but the reader's attention is called to some of the most interesting.[1] Since the writer's visit systematic studies of the birds and mammals of the park have been made by Mr. A. H. Howell, of the United States Biological Survey, who visited the region twice during the year 1918. The results of his investigations will be published later by the Survey.

In southern Florida many well-known birds, as well as mammals, are represented by varieties or subspecies quite distinct from the typical forms occurring farther north. In some cases the differences are in the relative proportions of certain parts; in others it may be in the coloration of one or both of the sexes. Thus we have a Florida

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[1] Illustrations, descriptions, and scientific names of many of the birds here considered will be found in the admirable little pocket bird guides of Chester A. Reed, published by Doubleday, Page & Co.

quail, Florida crow, Florida wren, and the Florida cardinal, all of which are essentially Floridian, and the Florida wild turkey, which is fast disappearing. Other forms called Floridian, because they were first described from Florida, but which have a wider geographical range, are the Florida gallinule, several Florida hawks, the Florida screech owl and barred owl, and the Florida blue jay. One of the most beautiful birds, a tropical species now fast disappearing from Florida and occurring nowhere else in the United States except in Texas, is the roseate spoonbill.

Of this species, known scientifically as *Ajaia ajaja* (pl. 54) Mrs. Kirk Munroe has written a most charming description, which the writer hoped to embody in the present paper, but which, on account of limited space, can not be here presented in full.

> Once the roseate spoonbill inhabited the neighborhood of Paradise Key in great flocks, but it is becoming rarer and rarer. * * * They are sociable birds, always traveling and nesting in communities. The nests, usually built among picturesque mangrove branches, look like a pile of rubbish, except in the very center, where three or four whitish, brown-spotted eggs are placed. Young spoonbills are covered with snowy down while they are nestlings. In feeding they push their bill, indeed the entire head, down the parent's throat as far as possible to secure food, each greedy little designing taking its turn. The spoonbill is sometimes called the shoveler on account of the peculiar shape of its beak, which it uses with wonderful skill in catching aquatic insects and crustaceans in the mud along the water's edge. Quantities of its beautiful, rose-colored feathers were sold to tourists a few years ago. In certain localities exploring naturalists came upon great piles of carcasses from which the beautiful wings had been torn. No wonder that this unfortunate bird, whose beautiful plumage like that of the egret has been its curse, has become almost extinct in Florida. Thanks to the influence of the Audubon societies, the feathers of wild birds are becoming more and more unfashionable, and it is hoped that the roseate spoonbill may thus escape extermination.

The white ibis, another bird belonging, like the spoonbill, to the heron order, is quite common in the vicinity of Royal Palm State Park. It is easily recognized by its white body plumage, black-tipped wings, and decurved, orange-red beak, with which it is most adept in extracting crawfish and aquatic insects from the mud of the marshes. To the same order also belong the American bittern, a brownish bird with greenish-yellow legs; the Ward heron, stately "lady of the waters," with slate-colored back, mostly white under parts, and whitish crest; the little blue heron, not always blue, but sometimes pure white, also common about Paradise Key; and the black-crowned and the yellow-crowned night herons, whose "day begins after sunset," when they leave their roosts in the forests and fly forth to feed in the marshes.

Among the diving birds are the pied-billed grebe, also known as the water witch or hell-diver, a bird easily recognized by its lobed feet. The darters are represented by the uncanny water turkey, or

snake bird (*Anhinga anhinga*), quite common in trees near the slough of the park. This bird, like a submarine, dives with the greatest ease and pursues its prey beneath the surface of the water.[1] There is little open water to attract ducks, but the park warden has every year observed, in the vicinity of the park, a few blue-winged teal, mallard, and Florida ducks (*Anas fulvigula*), the latter remaining throughout the entire year.

The turkey vulture commonly seen sailing in the sky above Paradise Key is *Cathartes aura* that ranges over North and South America, called *Tzopilotl* by the Aztecs and *Gallinazo* by Spanish Americans. Specimens of it were caught by Mr. A. H. Howell in traps set on the marshes for raccoons.

FIG. 28.—OSPREY, *Pandion haliaetus carolinensis*, WHICH CATCHES FISH IN THE FLOODED EVERGLADES.

Among the birds of prey are the Everglade kite (*Rostrhamus sociabilis*), which feeds upon the large marsh snail already described and is known locally as the snail hawk; the swallow-tailed kite (*Elanoides forficatus*), with a deeply forked tail, white under parts and head and bluish black back, a bird quite common near the park and ranging to Central and South America; and the Mississippi kite (*Ictinia mississippiensis*). The hawks include the marsh hawk, sharp-shinned hawk, red-tailed hawk, Florida sparrow hawk, the osprey (fig. 28), and the Florida red-shouldered hawk. Many ospreys (*Pandion haliaetus carolinensis*) were observed by the writer flying over the Everglades between Paradise Key and Camp Jackson, occasionally darting down into the flooded grassy prairie and emerging with a good-sized fish in their talons. This species also occurs in Porto Rico, where it frequents both the coast and inland swampy lagoons.[2] On that island it is sometimes called *aguila* (eagle) on account of its noble eagle-like appearance. A magnificent specimen of the handsome red-shouldered hawk (*Buteo lineatus alleni*) perched habitually on the limb of a tree in front of the lodge during the visit of the writer to the park. From its station it pounced upon its prey, principally insects, lizards, and frogs, in the clearing before the building. It also catches snakes. The park warden

[1] The writer is greatly indebted to Mr. Francis Harper, of the U. S. Biological Survey, for notes on the water birds of Florida.

[2] See the interesting report of Mr. Alexander Wetmore on the birds of Porto Rico, U. S. Dept. Agr. Bull. 326. 1916.

took this bird as an illustration of the conditions of life on Paradise Key, using the following parody on the well-known House-that-Jack-built. "This is the hawk that caught the snake, that swallowed the rat, that ate the fruit, that fell from the palm, that grew from the seed that the bird dropped."

Among the swamp dwellers are the limpkin (*Aramus vociferus*), an odd bird intermediate between the cranes and rails, with olive-brown plumage streaked with white; and the Carolina rail, or sora (*Porzana carolina*), a modest-colored, shy bird, which remains concealed in the vegetation of the marshes during the day and does not reveal its presence until the late afternoon, when it begins to utter its whistling note, and continues it long after night has fallen. A chorus of these birds has been compared to that of piping Hylas in the early spring.[1] To this group also belong the purple gallinule and the Florida gallinule, the former with resplendent plumage, a blue shield on its forehead and a carmine bill tipped with yellow, the latter with brownish plumage, a red frontal shield and a broad red band above its knee. Another allied bird is the coot, or mud hen (*Fulica americana*), distinguished by its whitish frontal shield and especially by its lobed or scalloped toes, which are not unlike those of a grebe. Kildeers (*Oxyechus vociferus*) are very common, filling the air with their shrill cries, as though in a perpetual state of alarm.

In addition to the well-known mourning dove, there is a beautiful, little ground dove (*Chaemepelia passerina*) on Paradise Key. A closely allied variety of the latter collected in Porto Rico by Mr. Alexander Wetmore, of the United States Biological Survey, was found to have swallowed a number of ground pearls, or margarodes, already described, which Mr. Wetmore thinks may have been picked up by mistake for gravel to aid digestion.[2]

Other birds recorded from this region are the yellow-billed cuckoo; several woodpeckers, including the rare ivorybill; a screech owl, already mentioned, which offers a pleasant contrast to some of the unspeakable spiders and insects mentioned in this paper by its conjugal fidelity and parental affection, for it remains mated for life and defends its young most courageously; the whippoorwill, which is a winter resident, the allied Chuck-will's-widow and the Florida nighthawk; our own little ruby-throated hummingbird; the kingbird; the crested flycatcher; the phœbe; purple martin; barn swallow; tree swallow; mockingbird; catbird; long-billed marsh wren; and the Florida wren already mentioned. To the last-named

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[1] See Chapman, Birds of Eastern America, 3d ed., p. 143. 1896.

[2] Many other birds of this region occur also in the West Indies, or are there represented by closely allied varieties or subspecies. The reader's attention is called to Mr. Wetmore's monograph on the Birds of Porto Rico already quoted, issued as U. S. Dept. Agr. Bull. No. 326. 1914.

bird (*Thryothorus ludovicianus miamensis*) Mrs. Kirk Munroe has paid a well-deserved tribute.

Following these in the bird census of the park come the ruby-crowned kinglet; the wood thrush; Wilson thrush, Hermit thrush, American robin (*Planesticus migratorius*) and bluebird (*Sialia sialis*); the Florida blue jay, Florida crow, and the fish crow; a number of wood warblers, including the beautiful little ovenbird (*Seiurus aurocapillus*), which comes daily to the door of the park lodge to be fed with scraps from the table; the Florida yellowthroat; and the American redstart (*Setophaga ruticilla*). During the writer's visit to the park several individuals of this beautiful bird were frequent visitors to a blooming marlberry tree (*Icacorea paniculata*) in quest of insects attracted by its fragrant, elderlike blossoms.

The list of birds terminates with the names of several vireos, the scarlet tanager, summer tanager; the American goldfinch; the Savannah sparrow, which is a pest in the seed beds of neighboring truck farmers; the Florida cardinal, the female of which is more deeply colored than in our own variety; the blue grosbeak; the indigo bunting; and the many-colored painted bunting, or nonpareil. One would think that the last-named bird (*Passerina ciris*) would be highly conspicuous in its natural habitat; but Doctor Oberholser, who is a keen observer, says that it is often difficult to detect in the dense undergrowth which it frequents, for the bright colors of its varied plumage act as a kind of camouflage or disguise.

MAMMALS.

Among the strange animals which early explorers encountered in the New World the two which excited most wonder were the opossum and the strange, aquatic manatee, both of which were unlike anything ever before seen. The imperfect descriptions of the manatee gave rise to tales of sirens, and the exaggerated accounts of the animal which carried its young in pouches made of its own skin resulted in various fanciful pictures.

In southern Florida several of our familiar animals are represented by varieties slightly different from northern forms, varying either in color, size, or relative proportion of the parts. Thus the mammal fauna of the Royal Palm State Park includes the Florida opossum, *Didelphis virginiana pigra*, very similar to our northern type but somewhat smaller and with a longer and more slender tail; the cotton rat of south Florida, *Sigmodon hispidus spadicipygus*; the south Florida rice rat, *Oryzomys palustris coloratus*, aquatic in its habits and an excellent swimmer; the Florida cotton mouse, *Peromyscus gossypinus palmarius*, very abundant in the forest; the Flor-

ida marsh hare, *Sylvilagus palustris paludicola;* the Florida wild-cat, *Lynx ruffus floridanus*, still very common in Paradise Key and in the hammocks between Royal Palm State Park and Miami, and even within the city limits of Miami; the Florida panther, *Felis coryi*, now nearly extinct, but said to be an occasional visitor to Paradise Key; the Florida otter, *Lutra canadensis vaga*, not uncommon in the sloughs of the park; the Florida raccoon, *Procyon lotor elucus*, of a more yellowish color than our northern type; the Florida bear, *Ursus americanus floridanus*, an occasional visitor to the park; the Florida deer, *Odocoileus virginianus osceola*, a dark colored, little animal, about one-quarter smaller than our Virginia deer.

In addition to the above mammals, the manatee, *Trichechus latirostris*, already mentioned, should be included; for, although it does not occur in the immediate vicinity of the park, it is not uncommon in the Miami and other streams close by, into which it enters to feed upon the aquatic vegetation. Its favorite food is the so-called manatee grass, *Cymodocea manatorum*, to which it gives the specific name. During the writer's visit to Miami he saw a fine specimen of this strange animal in captivity, which was fed daily with great quantities of this succulent weed.

For a résumé of the work which has thus far been done in this branch of zoology, the reader is referred to a paper on "The land mammals of peninsular Florida and the coast region of Georgia," by Outram Bangs,[1] in which it is pointed out that the chief cause of the occurrence of so many well-defined subspecies of animals is the isolated position of southern Florida which, like that of an island, has resulted in the segregation of groups and the development of special breeds or distinct forms.

INDIANS OF SOUTHERN FLORIDA.

Many of those who have visited southern Florida have had their attention called to the shell mounds and other prehistoric vestiges of human habitation found in many places along the coast. Some of the most remarkable of these, situated at Marco, or San Marcos, on the Gulf coast of southern Florida, were investigated in 1896 by the late Frank Hamilton Cushing, who, among other things, found the remains of remarkable terraces constructed almost entirely of the shells of conchs, *Fulgur perversum*, a species which takes its specific name from the perverse, or left-handed twist of its spiral shell.[2] Among the objects unearthed were many made wholly or in part of these shells: Mattocks or hoes (fig. 20), war clubs, ladles for baling canoes, drinking cups, spoons, and even boat anchors, the latter

[1] Proceedings Bost. Soc. Nat. Hist., 28: 157 to 235. 1898.

[2] See Cushing's report in the Proceedings of the American Philosophical Society, vol. 35, pp. 329–448. 1896.

made by securing several of the largest shells together, with cordage made of agave or yucca fiber, which also served as the cable. An interesting fact connected with these objects is that similar utensils made of this same shell, easily recognizable by its "perverse" spiral, have been unearthed in the mounds of the valleys of the Mississippi and its tributaries, which tend to connect the Florida mound builders with those of our great inner basin. Objects made from the shells of *Fulgur perversum* taken from the mounds of Florida, Arkansas, Tennessee, Ohio, Indiana, Illinois, and Missouri may be seen in the collections of the United States National Museum. Plate 55 is a photograph by Cushing of a terrace faced with these shells; plate 56 shows a ladle made of one of the shells with the inner whorls removed; and figure 30 shows a spoon unearthed in Florida compared with a similar one found in a mound in eastern Tennessee.[1]

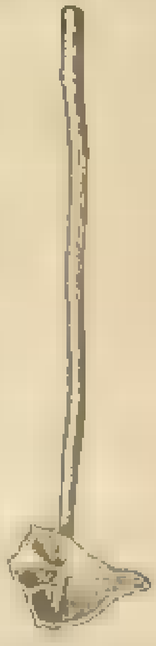


FIG. 29.—MATTOCK OR WAR-CLUB MADE FROM SHELL OF *Fulgur* (*Busycon*) *perversum*, SIMILAR TO SPECIMENS FOUND IN GRAVES OF THE MOUND BUILDERS OF THE MISSISSIPPI VALLEY.

FIG. 30.—UTENSILS MADE OF SHELLS OF *Fulgur* (*Busycon*) *perversum*. *a*, CUP IN THE UNITED STATES NATIONAL MUSEUM FROM THE WEST COAST OF SOUTHERN FLORIDA; *b*, PERFORATED SHELL FROM MOUND IN EASTERN TENNESSEE. REDUCED.

Nearly all accounts of the aboriginal inhabitants of Florida refer to utensils made of these shells, especially in connection with the celebrated "black drink" ritual, in which the shells were used as dippers and drinking cups for serving this ceremonial decoction. The earliest illustrations,[2] however, evidently drawn from memory, erroneously represented these utensils as being made of a shell shaped like that of a nautilus instead of the species actually used.

[1] See MacCurdy, in Proceedings of the Nineteenth International Congress of Americanists, p. 70, fig. 27. 1915.

[2] See Lemoine's illustration [1564] reproduced in the writer's paper on the Narcotic plants and stimulants of the ancient Americans, in the Smithsonian Report for 1916, pl. 14. 1917.

ABORIGINAL TRIBES.

Very little is known about the aboriginal Indians of southern Florida. The Seminoles, as every one knows, are comparatively recent intruders in this region. At the time of the discovery the most important tribe was known as the Calusas, or Caloosas, from whom the Caloosahatchee River takes its name. Their territory extended from Tampa Bay southward to Cape Sable, eastward to Cape Florida, including the outlying *cayos*, or keys, and inland to Lake Okeechobee. They claimed authority over the east coast tribes as far north as Cape Canaveral. It was they who, in 1513, repelled Ponce de Leon and kept him from landing on their coast. They were cruel and piratical, killing shipwrecked mariners, and enriching themselves by robbing stranded vessels. The most authentic account of them is given by Fontaneda, who lived among them as a captive. According to him, they ate bread made of certain roots the greater part of the year, but sometimes the roots could not be gatherered on account of floods to which the country was subject. They also had an abundance of fish and of roots resembling truffles, as well as many other kinds, and when they went hunting deer or birds they ate venison or fowl's flesh. These Indians did not wear clothing; the men went naked, except for tanned deerskins or mats woven of straw of which they made breechcloths; the women wore moss "which grows from the trees, resembling oakum or wool, which is not white but gray, and with these weeds they covered themselves around the waist."[1] Their weapons were bows and arrows and throwing sticks or spears.

In the sixteenth century a tribe known as the Tequestas occupied the coast of southeastern Florida within the present limits of Dade and Monroe counties. Like the Caloosas, they were savage and piratical. About the year 1600 they carried on a regular trade with Habana in fish, skins, and ambergris, a grayish, waxlike substance secreted in the liver or intestines of the spermaceti whale (*Catodon macrocephalus*). This is lighter than water and sometimes occurs in great masses floating on the surface of the ocean. Formerly it was collected in considerable quantities on the shores of the Bahama Islands and the east coast of Florida. When heated it emanates a delightful fragrance, on which account it was at one time much used in perfumery. It was also used in medicine and believed to have aphrodisiac properties.

[1] "Estos Indios no visten Ropa, ni menos las Mujeres; andan desnudos los Hombres, si no es unos Pellejos de Venado curtidos, con que hacen unos Bragueros y se cubren solamente sus Verguenzas, y las Mujeres, unas Pajuelas que nacen de los árboles, á manera de Estopa ó Lana, y no es blanca, sino parda, y con aquellas Yerbas se cubren dellas á la redonda de la Cinta."

The most complete account available of the Indians who preceded the Seminoles in southern Florida is that of Jonathan Dickenson, who in 1699 while on a vessel bound from Jamaica to Philadelphia, with his wife and infant child, was wrecked on the southeast coast of Florida.

Several editions of his narrative have been published, the first one appearing in Philadelphia in 1699. It is a pathetic story of suffering. He, his wife, and his companions were stripped of their clothing and all their possessions and most cruelly treated by the Indians, but the Indian women, taking pity on his infant child, suckled it when its mother's milk was exhausted. From his account, which agrees essentially with that of Fontaneda, an accurate idea may be gleaned of the appearance of the Indians, their food, domestic economy, weapons, etc.

They were of fine physique. The men went naked except for a triangular breechcloth plaited of straw and wrought with divers colors, with a belt of the same material about four fingers wide. A string from the lower corner passed between the legs and was tied to the two ends of the belt which met behind the back, and from the knot hung a bunch of silk grass (fiber of Yucca filamentosa) of a flaxen color resembling a horse's tail. They also had deerskin cloaks. Their long hair was coiled in a knot into which were stuck two bones, one shaped like a broad arrow, the other like a spearhead (fig. 31).

FIG. 31.—Aboriginal Indian of Southern Florida drinking from shell cup.

Their wigwams were made of small poles stuck in the ground, with the upper ends arched together, and thatched with palmetto leaves. The wigwam of the "cassekey" (cacique) was "about a man's height to the top," and within it was a "cabin," or platform, about a foot high, made with sticks and covered with a mat, which served as a settee and couch. At one village the cacique's house was about 40 feet long and 20 feet wide, covered with palmetto leaves, and within it on one side and at the two ends there was "a range of cabins or barbecue." In some places the houses were built upon mounds artificially constructed of shells. Dickenson describes a flood caused by a violent gale from the northeast, which caused the water to rise in the chief's house and obliged him to seek refuge in a house on a higher mound. The household utensils consisted of mats, bags of woven straw used for storing dried berries, baskets, gourds, and drinking cups made of sea shells. Though he does not describe their earthenware he mentions pots in which they brewed their ceremonial drink called cassine. Palmetto leaves were used as trays in serving food

Concerning their food Dickenson says:

> These people neither sow nor reap nor plant any manner of thing whatsoever, nor care for anything but what the barren sands produce. Fish they have as plenty as they please, but sometimes they would make it scarce for us, so that a meal a week was most commonly our portion, and three meals a rarity.

Oysters, clams, and other shellfish were also included in their menus, and they must have had venison and other game occasionally, for Dickenson mentions the use of deerskins for clothing. In fishing, torches were sometimes used at night, and Dickenson noticed a young Indian spearing fish with great dexterity by means of a "striking staff," which he threw at the fish and brought them to shore on the end of his staff. In two hours he got as many fish as would serve 20 men. This striking staff or spear must have been similar to a harpoon, with a foreshaft. Among the objects from southern Florida in the United States National Museum there are wooden spears having the foreshaft pointed with sharks' teeth. In addition to the spears, they are armed with bows and arrows, and many of them carried Spanish knives. They also had other objects of European origin which they had obtained from wrecks, and one of them had a supply of ambergris which he had collected along the shore and which he expected to sell to the Spaniards at a good price.

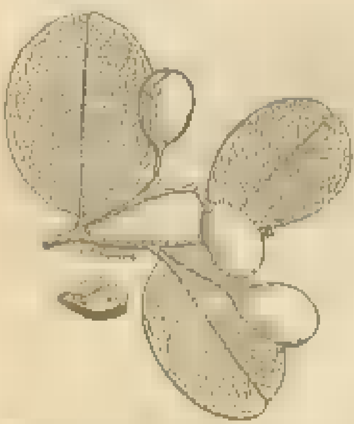


FIG. 32.—Coco plum, *Chrysobalanus pellocarpus*. Half nat. size.

Among the wild fruits eaten by the Indians, Dickenson mentions "seaside coco plums" (*Chrysobalanus icaco*) (fig. 32), "seaside grapes" (*Coccolobis uvifera*) (pl. 57), and palmetto berries, great stores of which were kept in their houses. The latter, which were undoubtedly the drupes of the saw palmetto (*Serenoa serrulata*) (pl. 58), may be considered the principal vegetable food staple of the Indians south of Jupiter Inlet. Dickenson found the coco plums and seaside grapes refreshing, but of the palmetto berries he says:

> Not one amongst us could suffer them to stay in our mouths, for we could compare them to nothing else than rotten cheese steeped in tobacco juice.[1]

Notwithstanding his dislike of these berries when he first encountered them, Dickenson and his companions became accustomed

[1] That this comparison is most apt was proved by the writer, who tasted some dried drupes of *Serenoa serrulata* in the collection of the Bureau of Plant Industry. They are not unlike small dates in appearance, with a seed resembling a brown bean, surrounded by scant pulp. The latter tasted very much like rancid cheese, with a slightly sweetish taste like that of certain kinds of chewing tobacco. (See pl. 58.)

to them, even stealing a bag of them for provisions on starting out for the north, and deploring the loss of a small quantity which was accidentally burned at night. Large supplies of palmetto berries were paid as tribute to the "King, or young Cassekey," of a town near the present site of Palm Beach, by the Indians of Santa Lucia, who were his vassals. On reaching St. Augustine, Dickenson says, his palate had become so changed by a diet of these berries that he could not endure the taste of salt.

The Indians were very fond of cassine (an infusion of *Ilex vomitoria*), which they used not only ceremonially, but also as a refreshing beverage. This plant (pl. 59) does not grow in southern Florida. Dickenson describes the joy with which the Indians received from the north a supply of its leaves, together with some vegetable product which they used as a tobacco substitute. Of tobacco they were immoderately fond. The Spanish officials in Florida, like those on the island of Guam in early days, used tobacco leaves in paying the Indians for supplies and for labor. At the time of which Dickenson wrote, the use of *Ilex vomitoria* tea was as common among the Spaniards of Florida as that of *Ilex paraguariensis* among the colonists of Paraguay and Uruguay. Like the latter it contains caffeine and is a pleasant stimulant. When very strong and taken immoderately it acts as an emetic.

From an ethnological point of view Dickenson's description of a ceremony accompanied by drinking cassine is the most interesting part of his narrative. His account follows:

> The Indians were seated as aforesaid, the Cassekey at the upper end of them, and the range of cabins was filled with men, women and children, beholding us. At length we heard a woman or two cry, according to their manner, and that very sorrowfully, one of which I took to be the Cassekey's wife; which occasioned some of us to think that something extraordinary was to be done to us; we also heard a strange sort of a noise, which was not like the noise made by a man, but we could not understand what, nor where it was; for sometimes it sounded to be in one part of the house, sometimes in another, to which we had an ear. And indeed our ears and eyes could perceive or hear nothing but what was strange and dismal, and death seemed to surround us; but time discovered this noise to us—the occasion of it was thus:
>
> In one part of this house, where a fire was kept, was an Indian man, having a pot on the fire, wherein he was making a drink of a shrub (which we understood afterwards by the Spaniards, is called Casseena) boiling the said leaves, after they had parched them in a pot; then with a gourd, having a long neck, and at the top of it a small hole, which the top of one's finger could cover, and at the side of it a round hole of two inches diameter. They take the liquor out of the pot and put it into a deep round bowl, which, being almost filled, contains nigh three gallons: with this gourd they brew the liquor, and make it froth very much; it looks of a deep brown color. In the brewing of this liquor was this noise made, which we thought strange; for the pressing of the gourd gently down into the liquor, and the air which it contained, being forced out of the little hole at the top, occasioned a sound, and according to the time

and motion given, would be various. This drink when made and cool to sup, was in a shell first carried to the Cassekey, who threw part of it on the ground, and the rest he drank up, and then would make a loud hem; and afterwards the cup passed to the rest of the Cassekey's associates, as aforesaid; but no other man, woman or child must touch or taste of this sort of drink; of which they sat sipping, chattering, and smoking tobacco, or some other herb instead thereof, for the most part of the day.

* * * * * * *

In the evening, we being laid on the place aforesaid, the Indians made a drum of a skin, covering therewith the deep bowl in which they brewed their drink, beating thereon with a stick, and having a couple of rattles made of a small gourd, put on a stick with small stones in it, shaking it; they began to set up a most hideous howling, very irksome to us; and sometime after came many of their young women, some singing, some dancing. This was continued till midnight, after which they went to sleep.

Of another ceremony he writes as follows:

It now being the time of the moon's entering the first quarter the Indians had a ceremonious dance which they began about 8 o'clock in the morning. In the first place came in an old man and took a staff about 8 feet long, having a broad arrow on the head thereof, and thence half way painted red and white like a barber's pole. In the middle of this staff was fixed a piece of wood, shaped like unto a thigh, leg, and foot of a man, and the lower part of it was painted black. This staff being carried out of the Cassekey's house was set fast in the ground, standing upright; which being done, he brought out a basket, containing rattles, which were taken out thereof and placed at the foot of the staff. Another old man came in and set up an howling like unto a mighty dog, but beyond him for length of breadth, withal making a proclamation. This being done, and most of them having painted themselves, some red, some black, some with black and red, with their bellies girt up tight as well as they could girt themselves with ropes, having their sheath of arrows at their backs, and their bows in their hands; being gathered together about the staff, six of the chiefest men in esteem amongst them, especially one who is their doctor, took up the rattles and began an hideous noise, standing round the staff with their rattles, and bowing without ceasing to it for about half an hour. Whilst these 6 were thus employed, all the rest were staring and scratching, pointing upwards and downwards, on this and the other side, every way, looking like men frightened or more like furies. Thus they behaved till the 6 had done shaking their rattles; then they all began to dance, violently stamping on the ground for the space of an hour or more, without ceasing; in which time they sweat in a most excessive manner, so that by the time the dance was over, by their sweat, and the violent stamping of their feet, the ground was trodden into furrows; and by morning the place where they danced was covered with maggots; thus often repeating the manner, they continu'd till about 3 or 4 in the afternoon, by which time many were sick and faint. Being gathered into the Cassekey's house they sat down, having some hot casseena ready, which they drank plentifully of, and gave greater quantities thereof to the sick and faint than to others; then they eat berries. On these days they eat not any food till night.

The next day, about the same time, they began their dance as the day before; also the third day they began at the usual time, when many Indians came from other towns, and fell to dancing, without taking any notice one of an-

other. This day they were stricter than the other two days, for no woman must look upon them: but if any of their women went out of their houses they went veiled with a mat.[1]

The Indians had narrow canoes in which they crossed inlets and rivers. When they visited outlying keys or wrecks they lashed two canoes together by transverse poles upon which they made platforms for carrying their effects. In this way they sometimes navigated as far as the island of Cuba. They appeared to be under the sway of the Spanish and showed hostility to all Englishmen or castaways whom they suspected of being English. Dickenson tells of the arrival of Spanish soldiers from St. Augustine, and describes the chagrin of the Indians when, instead of ill treatment, the Englishmen met with kindness at the hands of their rescuers, by whom they were taken to St. Augustine.

It may be of interest here to note the use of the acorns of the live oak (pl. 60) by the Florida Indians, who, after removing the bitter tannic acid by soaking the kernels in water, ground them up and made them into cakes or mush. The early Spaniards, when their supply of Mexican chocolate was exhausted, used these acorns as a substitute for cacao in preparing a chocolatelike drink, not, however, altogether satisfactory as a substitute, with which they regaled their guests.

In the wars between the Spanish and the English the Indians above described were loyal to the Spaniards, while the Creeks and several other more northerly tribes were allies of the English. Finally, in 1763, when Florida was ceded by Spain to England the "Spanish Indians" sought refuge on the outlying keys and many of them removed to Cuba. Among those that remained in Florida were the Muspahs, who maintained their individuality until the close of the Second Seminole War. Unfortunately nothing is known of the languages of these south Florida tribes, so that their linguistic relationship to other tribes can not be determined.

SEMINOLES.

As already stated, the Seminoles are comparatively recent intruders. They belong to the Muskhogean stock, and are therefore related to the Choctaws, Chickasaws, and Creeks, but not to the Timucuas encountered by the French Hugenots at the mouth of the St. Johns River. They are the descendants of immigrants from lower Creek towns who retreated to southern Florida in the eighteenth century.[2] The name by which they are now known, signify-

[1] Dickenson, Narrative of a Shipwreck in the Gulph of Florida, 6th ed., pp. 47–49, 1803.

[2] Much misinformation has been published regarding the origin of the Seminoles. One recent writer refers to them as descendants of the Aztecs, and at the same time connects

ing "runaways," was first applied to them about the year 1775. It is often stated that they are a mixed race, owing to intermarriage with refugee negroes; but it is quite certain that those now living in southern Florida (see pls. 61 and 62) are of pure blood, of fine physique, and dignified mien, speaking a language allied to the Choctaw uncorrupted by English. It is not within the scope of this paper to relate their history or to trace the causes which led to the Seminole wars, and the removal of a large proportion of the tribe west of the Mississippi. Those now living in Oklahoma have been organized into what is called the Seminole Nation. Concerning those remaining in Florida, much interesting information is given by Clay MacCauley in the Fifth Report of the Bureau of American Ethnology. The reader is also referred to Mrs. Minnie Moore-Wilson's sympathetic account of these Indians in her work entitled "The Seminoles of Florida"; and to the various works of Anthony Weston Dimock, dealing with Florida adventure, especially "Florida Enchantments" and "Dick Among the Seminoles." To Mr. Dimock the writer is indebted for the accompanying illustrations (pls. 61 and 62).

Unlike the Indians described by Dickenson, the Seminoles practice agriculture, cultivating maize, sweet potatoes, pumpkins, squashes, introduced melons, peanuts, sugar cane, guavas, pineapples, and various citrus fruits. Among the wild fruits eaten by them are seaside grapes (*Coccolobis uvifera*) (pl. 57) and coco plums (*Chrysobalanus icaco* and *C. pellocarpus*) (fig. 32); but in MacCauley's list the berries of the saw palmetto (*Serenoa serrulata*) are conspicuous for their absence. On the other hand, the Seminoles have an important food staple not mentioned by Dickenson, though the plant yielding it was very abundant in the region through which he passed. This is the koonti or coontie, a kind of cornstarch prepared from the roots of *Zamia floridana* (pl. 63), already described in this paper.

So highly do the Seminoles esteem the koonti that they declare it to be a special gift from God. An Indian named Ko-nip-ha-too related to MacCauley a legend in which it was declared that long ago the "Great Spirit" sent Jesus Christ to the earth with the precious plant from which it is prepared, and the place of his descent was at Cape Florida, where he gave the koonti to the red men.[1]

them with the ancient Egyptians and the Hebrews. The evidence offered to establish their relationship with the last named is that of a certain bishop, who heard a Seminole chant repeat the name [illegible], and identified it with that of Jehovah. The Indians confirmed "the wonderful, yes, startling observation" made by the bishop; and from the use of this name, chanted in the depth of the Everglade, "one may work back to the prehistoric ruined temples of Mexico and Yucatan, so similar to those of Egypt; and thus may find in Seminole speech a language link to connect the new world with the old." It is scarcely necessary to state that there is no linguistic relationship between the Muskhogean stock to which the Seminoles belong and the Aztecs of Mexico or the Mayas of Yucatan.

[1] See Fifth Annual Report Bur. Am. Ethn., p. 513. 1888.

Another coontie starch was obtained by the Florida Indians from the roots of certain species of smilax, commonly called China brier, but not specifically identical with the species described by Linnæus under the name *Smilax pseudo-china*. Three species were in all probability used for this purpose: *Smilax laurifolia*, growing in swampy places; the very similar *Smilax lanceolata*, growing in drier situations, and *Smilax auriculata* (pl. 64), growing in hammocks and on coastal sand dunes. William Bartram has given the following description of the preparation of red koonti from the roots of smilax:

They chop the roots in pieces, which are afterwards well pounded in a wooden mortar, then, being mixed with clean water in a tray or trough, they strain it through baskets; the sediment, which settles to the bottom of the second vessel, is afterwards dried in the open air, and is then a very fine, reddish flour or meal; a small quantity of this mixed with warm water and sweetened with honey, when cool, becomes a beautiful, delicious jelly, very nourishing and wholesome; they also mix it with fine corn flour, which being fried in fresh bear's oil makes very good hot cakes or fritters.[1]

Dr. John R. Swanton, of the Bureau of American Ethnology, has called attention to the fact that the name "koonti," "coonti," or "conte," is etomologically identical with "kánta" of the Alabama Indians now residing in Texas. His account follows:

In the course of my investigations among the Alabama (Alibamu) of Texas, I heard much of this plant, called by them *ka' nta*, and obtained a specimen of it, which Mr. Paul Standley of the National Museum has identified as *Smilax lanceolata*. It is evidently identical with a smilax that had been previously described to me as coonti by an old Creek Indian born in Alabama before the removal of the Creeks, "a brier that climbed up on trees like a vine."

After repeating Bartram's account of the preparation of smilax coontie as quoted above, he continues:

Hawkins also says the China brier "is called coonte," and he describes the way in which flour was extracted from it. It is therefore evident that at least two species of smilax were known as coonti by the ancient Creeks, and since the cycadaceous plant which now bears that name among the Florida Seminole is confined to southern Florida, it is evident that it could have been used only after the Seminole reached that country from the north. Originally it is evident that the term must have been applied to several species of smilax having large reddish roots.[2]

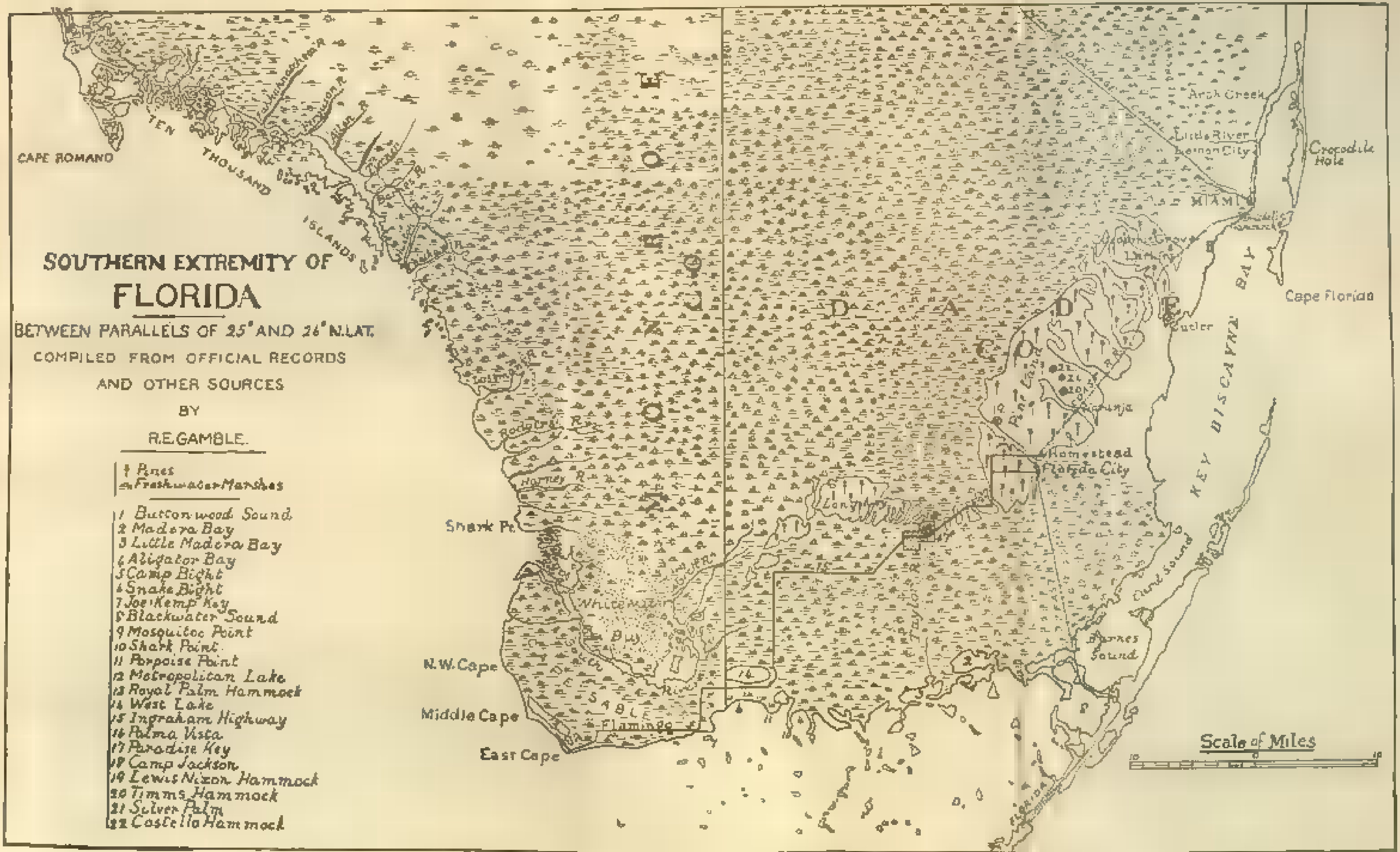
The roots of three species of smilax were tested for starch, at the writer's request, by Dr. Henry Hasselbring, of the Bureau of Plant Industry: *Smilax laurifolia*, *S. lanceolata*, and *S. auriculata*. The first showed no vestiges of starch, though this may have been because the rootstocks were old and woody. The second contained starch, but

[1] Bartram, William, Travels through North and South Carolina, Georgia, East and West Florida, etc., p. 241. 1791.

[2] American Anthropologist, vol. 15, pp. 141, 142. 1913.

this could not be extracted from the powdered rootstock in sufficient quantities to make a jelly. The third, figured on plate 64, which contained an abundance of starch, was subjected to a process like that described by Bartram, and yielded a delicate flesh-colored jelly, slightly acidulous and somewhat astringent. This jelly was quite equal to arrowroot when sweetened with sugar, for which it could be used as an excellent substitute.

It has been impossible within the limits of this paper to give a complete list of the plants thus far collected in the region here considered. It is hoped that such a list may be published later.



SOUTHERN EXTREMITY OF
FLORIDA
BETWEEN PARALLELS OF 25° AND 26° N.LAT.
COMPILED FROM OFFICIAL RECORDS
AND OTHER SOURCES
BY
R.E.GAMBLE.
Pines
Freshwater Marshes
1 Button-wood Sound
2 Madera Bay
3 Little Madera Bay
4 Aligator Bay
5 Camp Bight
6 Snake Bight
7 Joe Kemp Key
8 Blackwater Sound
9 Mosquitoe Point
10 Shark Point
11 Porpoise Point
12 Metropolitan Lake
13 Royal Palm Hammock
14 West Lake
15 Ingraham Highway
16 Palma Vista
17 Paradise Key
18 Camp Jackson
19 Lewis Nixon Hammock
20 Timms Hammock
21 Silver Palm
22 Costello Hammock
CAPE ROMANO
TEN THOUSAND ISLANDS
Arch Creek
Little River
Lemon City
Crocodile Hole
MIAMI
Cape Florida
Cutler
KEY BISCAYNE BAY
Homestead
Florida City
Shark Pt.
N.W. Cape
Middle Cape
East Cape
Flamingo
CAPE SABLE
Whitewater Bay
Barnes Sound
Card Sound
Scale of Miles
D A D E

484-1

1. VIEW OF PARADISE KEY FROM THE NORTHEAST, DRY SEASON, SHOWING ROYAL PALMS.

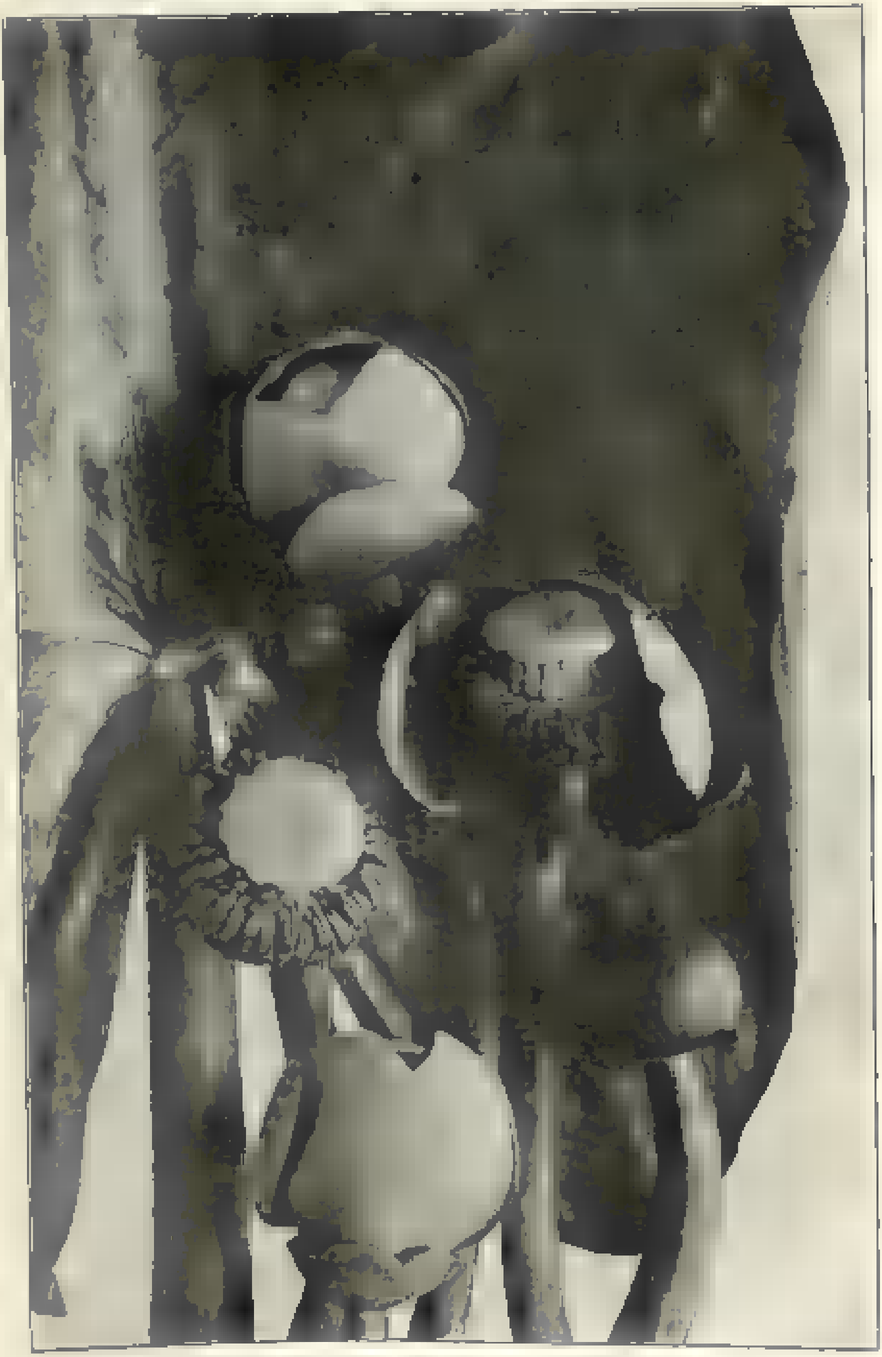
2. SAME VIEW AS ABOVE; EVERGLADES FLOODED.

OOLITIC LIMESTONE FROM ROYAL PALM STATE PARK, SHOWING CRUSTACEAN TUBE AND ANNELID CASTS ORIGINALLY FORMED IN CALCAREOUS MUD DEPOSITED IN A SHALLOW SEA.

Natural size. Photographed from specimens in United States National Museum.

SLOUGH AT THE EASTERN ENTRANCE TO ROYAL PALM STATE PARK, FILLED WITH A DENSE GROWTH OF YELLOW WATER LILIES (NYMPHAEA ADVENA, OR A CLOSELY RELATED SPECIES), PICKEREL WEEDS, ARROWHEADS, AND OTHER WATER PLANTS.

Photograph by Wilson Popenoe.



YELLOW WATER LILIES, OR BONNETS (NYMPHAEA ADVENA).

Natural size.

SEDGES FROM ROYAL PALM STATE PARK.

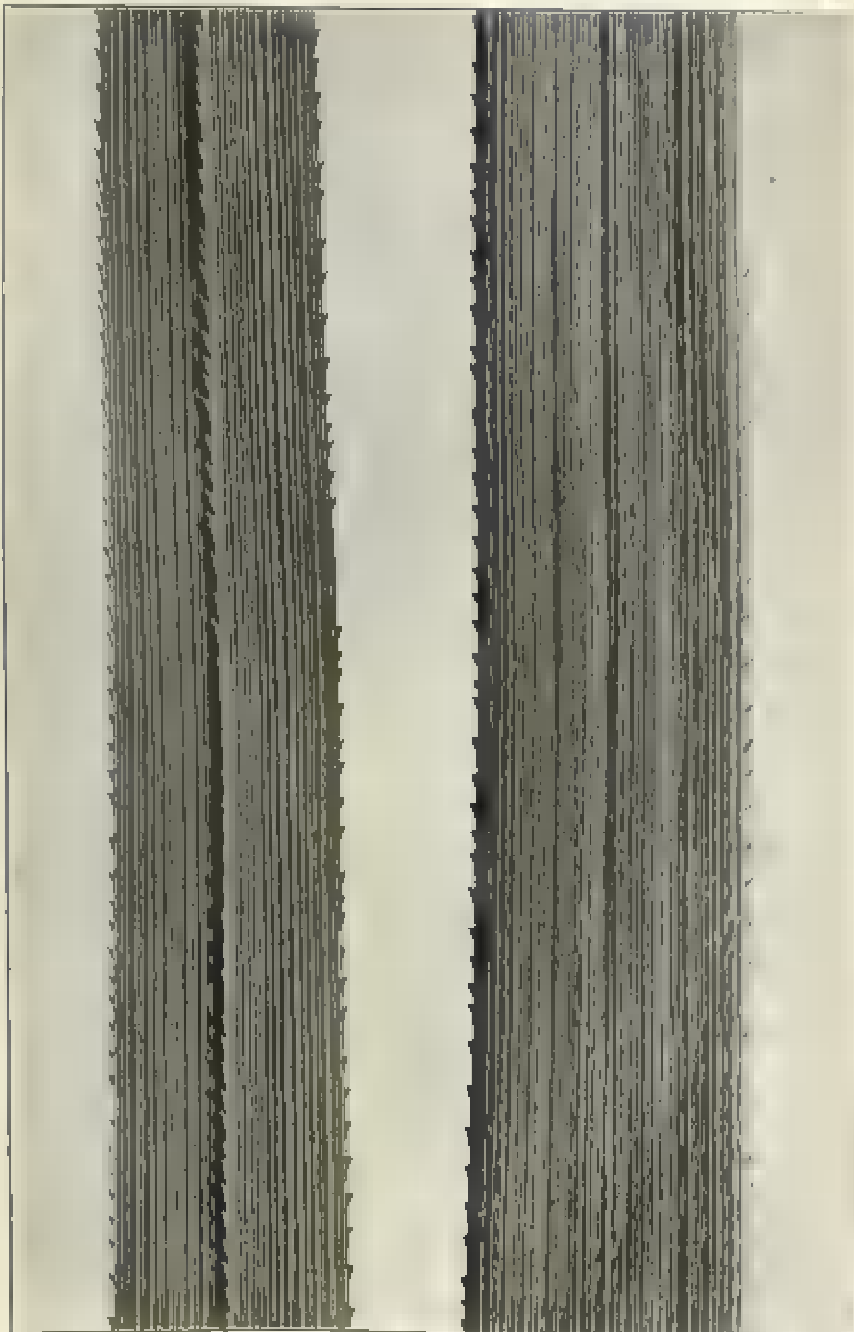
(1) *Rhynchospora corniculata*; (2) *Rhynchospora tracyi*; (3) *Cyperus* [illegible]; (4) *Cyperus haspan*; (5) *Fuirena breviseta*; (6) *Dichromena colorata*. Natural size.

GRASSES FROM ROYAL PALM STATE PARK.

(1) *Manisuris rugosa*; (2) *Paspalum monostachyum*; (3) *Panicum virgatum*; (4) *Panicum condensum*; (5) *Andropogon cabanisii*; (6) *Phleum pratense*; (7) *Chloris glauca*; (8) *Panicum adidum*. Natural size.

MARISCUS JAMAICENSIS (CLADIUM EFFUSUM TORR.), THE DREADED "SAW GRASS" OF THE EVERGLADES.

Natural size.



LEAVES OF SAW GRASS (MARISCUS JAMAICENSIS) ENLARGED SO AS TO SHOW CUTTING TEETH OF MARGINS AND KEEL.

ALLIGATOR APPLE (ANNONA GLABRA).

Very abundant on Everglade Keys. Its remarkably light wood is used for corks and for floats of fishing nets. Natural size.

BACCHARIS GLOMERULIFERA, A SHRUBBY COMPOSITE VERY COMMON IN MARSHES AND THE MARGINS OF EVERGLADE KEYS.

The male and the female flowers are borne on separate plants. Natural size.

BUTTON MANGROVE (CONOCARPUS ERECTA), SHOWING CLUSTERS OF FRUIT AND NECTARIES ON EACH SIDE OF THE PETIOLES.

Photograph of specimens collected by C. E. Mosier from the neighborhood of Royal Palm State Park. Natural size.

SWAMP CYPRESS (TAXODIUM DISTICHUM), SHOWING BUDDING BRANCH AND MATURE FRUIT.

Natural size.

ROYAL PALM STATE PARK. TENT OF WARDEN NEAR EASTERN ENTRANCE.

Photograph by Wilson Popenoe.

SATIN-LEAF (CHRYSOPHYLLUM OLIVAEFORME), SHOWING FLOWERS, FRUIT, AND SATIN LINED LEAVES.

Natural size.

ROOTS OF STRANGLING FIG (FICUS AUREA) EMBRACING CABBAGE PALM.

Photograph by Wilson Popenoe.

ERYTHRINA ARBOREA, USUALLY A SCRAMBLING SHRUB OF MODERATE SIZE BUT HERE GROWING IN THE FORM OF A LIANA.

Specimen growing near the eastern entrance to the park. Photograph by Roy D. Goodrich.

PISONIA ACULEATA, CALLED COCKSPUR ON ACCOUNT OF ITS SHARP RECURVED SPINES: A PLANT OF WIDE TROPICAL DISTRIBUTION; USUALLY A SCRAMBLING SHRUB. HERE A GIANT LIANA OF THE FOREST.

Showing C. E. Mosley, the park warden, at the base of the plant. Photograph by Roy D. Goodrich.

SWAMP BAMBOO-BRIER (SMILAX LAURIFOLIA), SHOWING JOINTED TUBEROUS ROOTSTOCK.

The globose black seeds were sometimes strung into necklaces by the aboriginal Indians. Natural size.

SPANISH MOSS (DENDROPOGON USNEOIDES), AN EPIPHYTE BELONGING TO THE PINE-APPLE FAMILY, USED BY THE ABORIGINAL INDIANS FOR MAKING SKIRTS AND APRONS.

Photograph received from Mrs. W. S. Jennings.

TILLANDSIA UTRICULATA, AN AIR-PLANT, OR EPIPHYTE, BELONGING TO THE PINEAPPLE FAMILY.

Photographed by Wilson Popenoe.

PHLEBODIUM AUREUM, A FERN GROWING IN THE AXILS OF OLD LEAVES ON THE TRUNKS OF CABBAGE PALMS. PORTION OF A FROND.

Natural size.

THE ROYAL FERN (OSMUNDA REGALIS): STERILE AND FRUITING FRONDS.

Natural size.

ANEMIA ADIANTIFOLIA (ORNITHOPTERIS ADIANTIFOLIA SW.), STERILE AND FRUITING FRONDS.

Natural size.

ROYAL PALMS (ROYSTONIA REGIA) OF PARADISE KEY, FROM WHICH ROYAL PALM STATE PARK DERIVES ITS NAME.

Photograph by Wilson Popenoe.

PAUROTIS WRIGHTII (SERENOA ARBORESCENS SARG.), THE TREE SAW PALMETTO.

This species forms clumps on the south coast of Florida, but does not occur within the limits of the park. Natural size.

PLATE 27.

[illegible]

FRUIT AND SEEDS OF FLORIDA PALMS.

PINUS CARIBAEA, THE ONLY PINE GROWING IN THE VICINITY OF ROYAL PALM STATE PARK. FASCICLED LEAVES; OPEN AND CLOSED CONES.

Natural size.

PINE LAND NEAR ROYAL PALM STATE PARK.

Beneath the pines (*Pinus caribaea*) grow the dwarf Saw Palmetto, the Silver Palm, the Cycad, *Zamia floridana*, a crimson-flowered morning-glory (*Exogonium microdactylum*) and the Twining Apocynaceous, *Echites echites*. Photograph by Wilson Popenoe.

ZAMIA FLORIDANA, AN ENDEMIC CYCAD FROM THE STARCHY ROOT OF WHICH FLORIDA ARROWROOT IS MADE; MALE INFLORESCENCE.

Natural size.

ZAMIA FLORIDANA; FEMALE CONE, SHAPED LIKE AN EAR OF MAIZE, BEARING ROWS OF SEEDS INCLOSED IN SCARLET ARIL AND COVERED BY A VELVETY PERICARP.

Natural size.

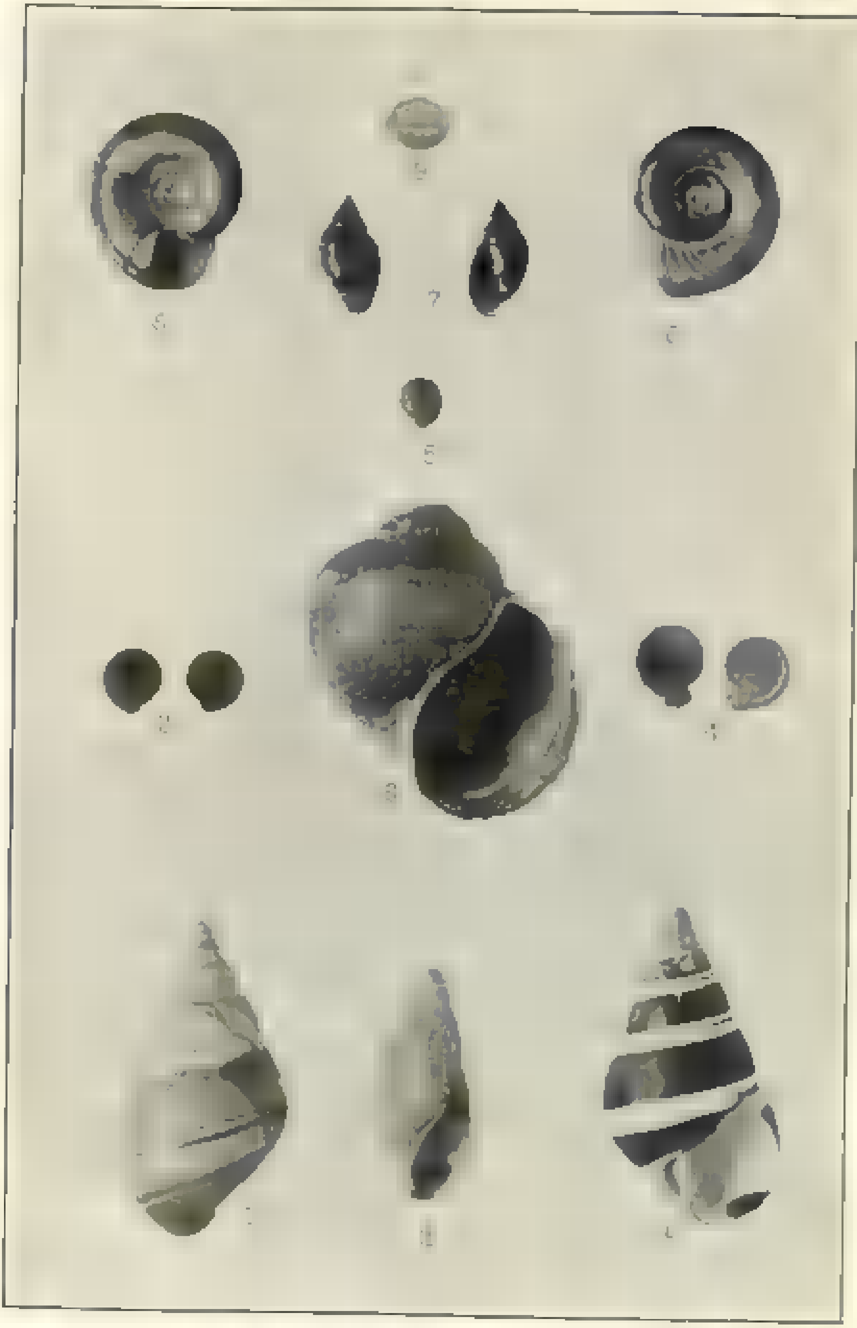
THORN TWIG, BUMELIA RECLINATA, A PINE-LAND SHRUB BELONGING TO THE SAPOTE FAMILY.

Natural size.

DWARF FLORIDA PRIVET, FORESTIERA PINETORUM, AN ENDEMIC PINE-LAND SHRUB OF SOUTHERN FLORIDA.

Natural size.

TREE SNAILS AND MARSH SNAILS OF PARADISE KEY



MOLLUSKS OF ROYAL PALM STATE PARK.

1, Tree shells, *Liguus fasciatus*; 2, Cannibal snail, *Glandina truncata*; 3, *Polygyra septemvolva volvoxis*; 4, *Polygyra uvulifera*; 5, *Helicina orbiculata tropica*; 6, *Planorbis duryi*; 7, *Physa gyrina*; 8, *Ampullaria depressa*; 9, *Musculium partumeium*. Natural size.

EVERGLADE CRAWFISH (CAMBARUS FALLAX), AN IMPORTANT FOOD-STAPLE OF THE WHITE IBIS AND OTHER MARSH BIRDS.

Natural size. Determined by W. L. Schmitt.

SCORPIONS (CENTRURUS GRACILIS) AND WHIP SCORPION (MASTIGOPROCTUS GIGANTEUS) FROM PARADISE KEY.

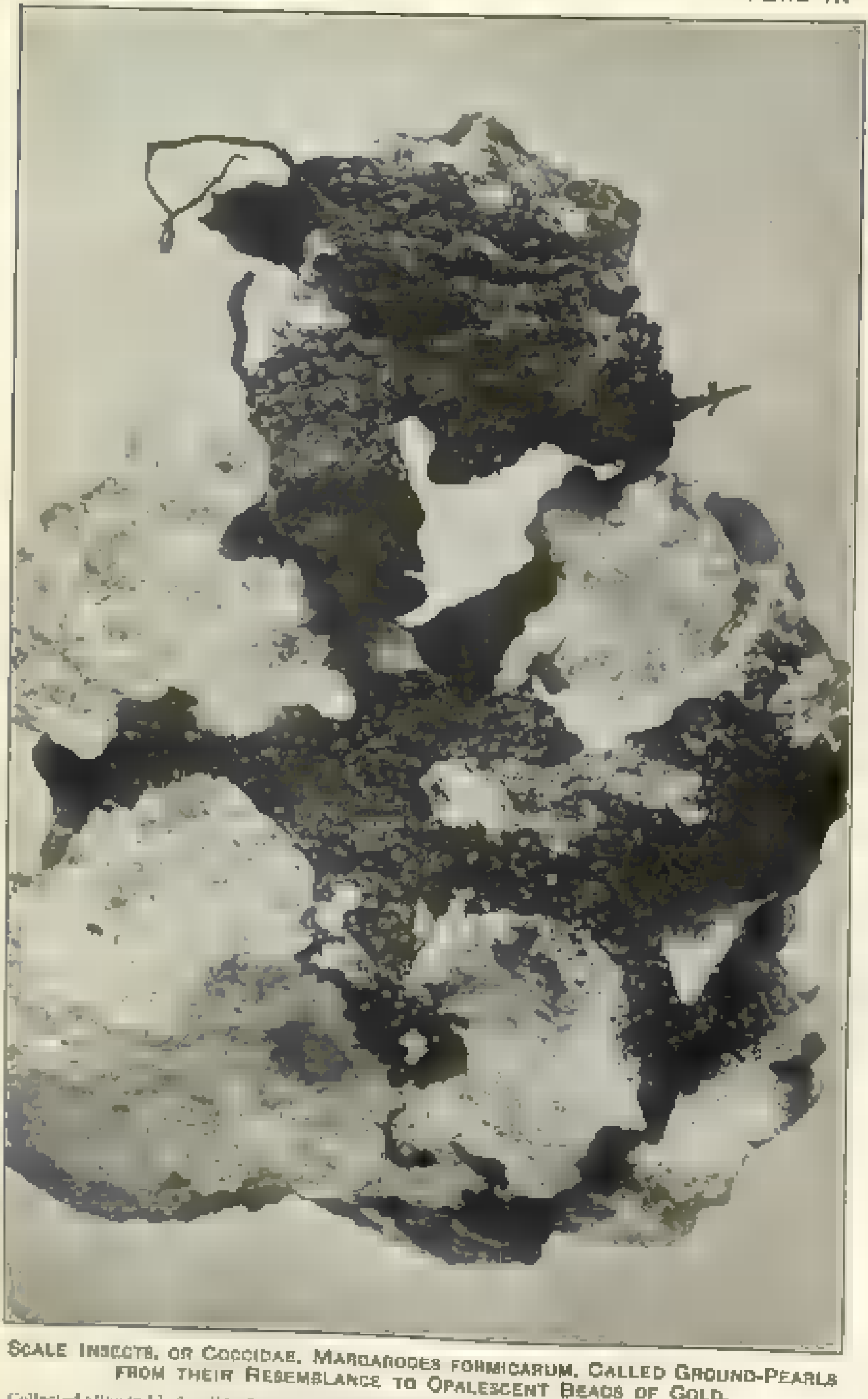
Determined by Dr. Nathan Banks. Slightly enlarged.

DOOR CASING OF SOUND OAK TIMBER RIDDLED BY WHITE ANTS (LEUCOTERMES), SHOWING RUNWAYS COATED WITH EARTH AND EXCRETED WOOD.

Natural size. Photograph by Thomas E. Snyder.

DRAGON FLIES OF ROYAL PALM STATE PARK.

1, *Celithemis eponina*; 2, *Gynacantha nervosa*; 3, *Ischnura ramburii*; 4, *Argiallagma minutum*; 5, *Libellula auripennis*. Natural size. Determined by Bertha P. Currie.

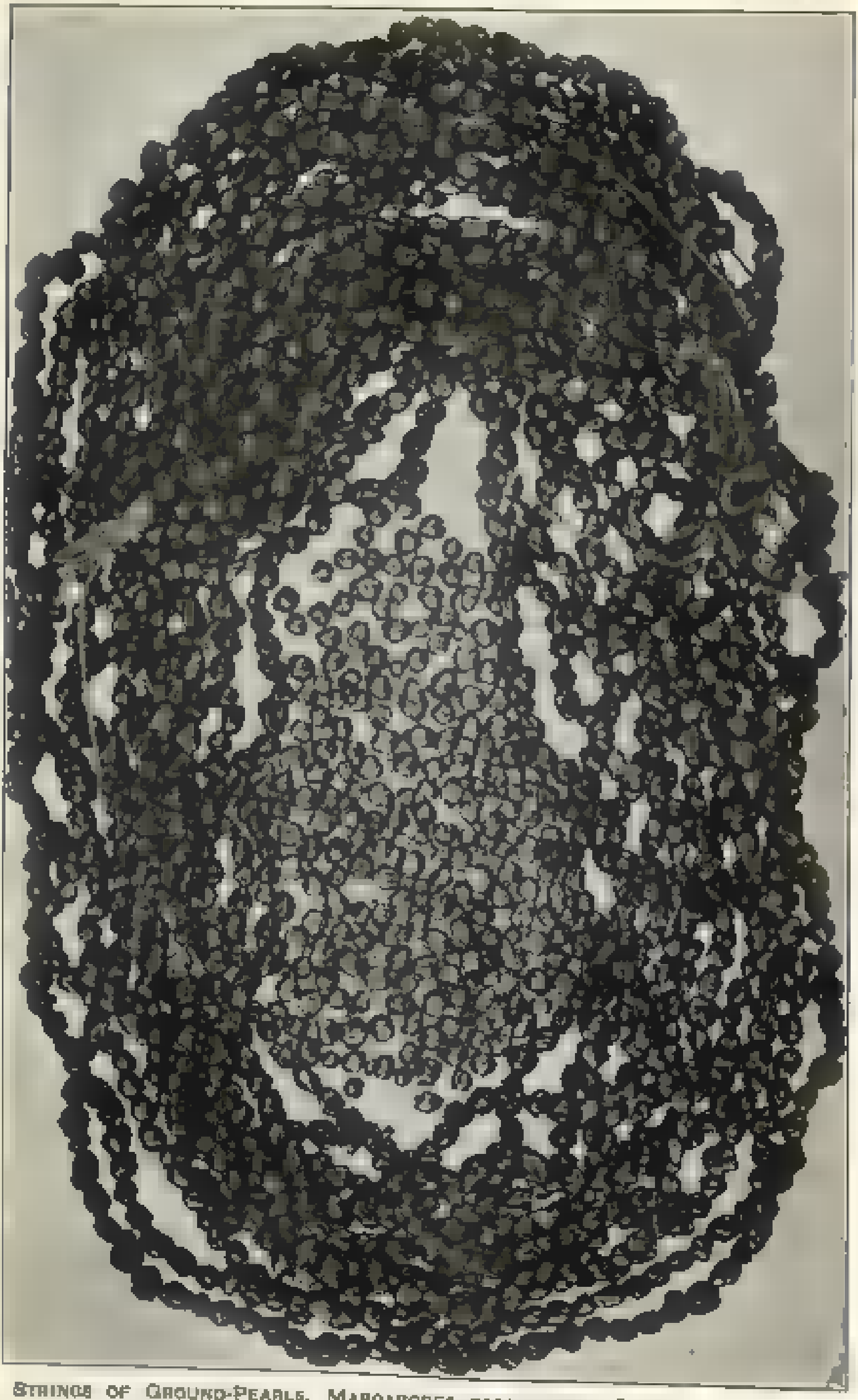


SCALE INSECTS, OR COCCIDAE, MARGARODES FORMICARUM, CALLED GROUND-PEARLS FROM THEIR RESEMBLANCE TO OPALESCENT BEADS OF GOLD.

Collected alive in black soil in fissure of oolitic limestone near Park Lodge by C. E. Mosier. Natural size.

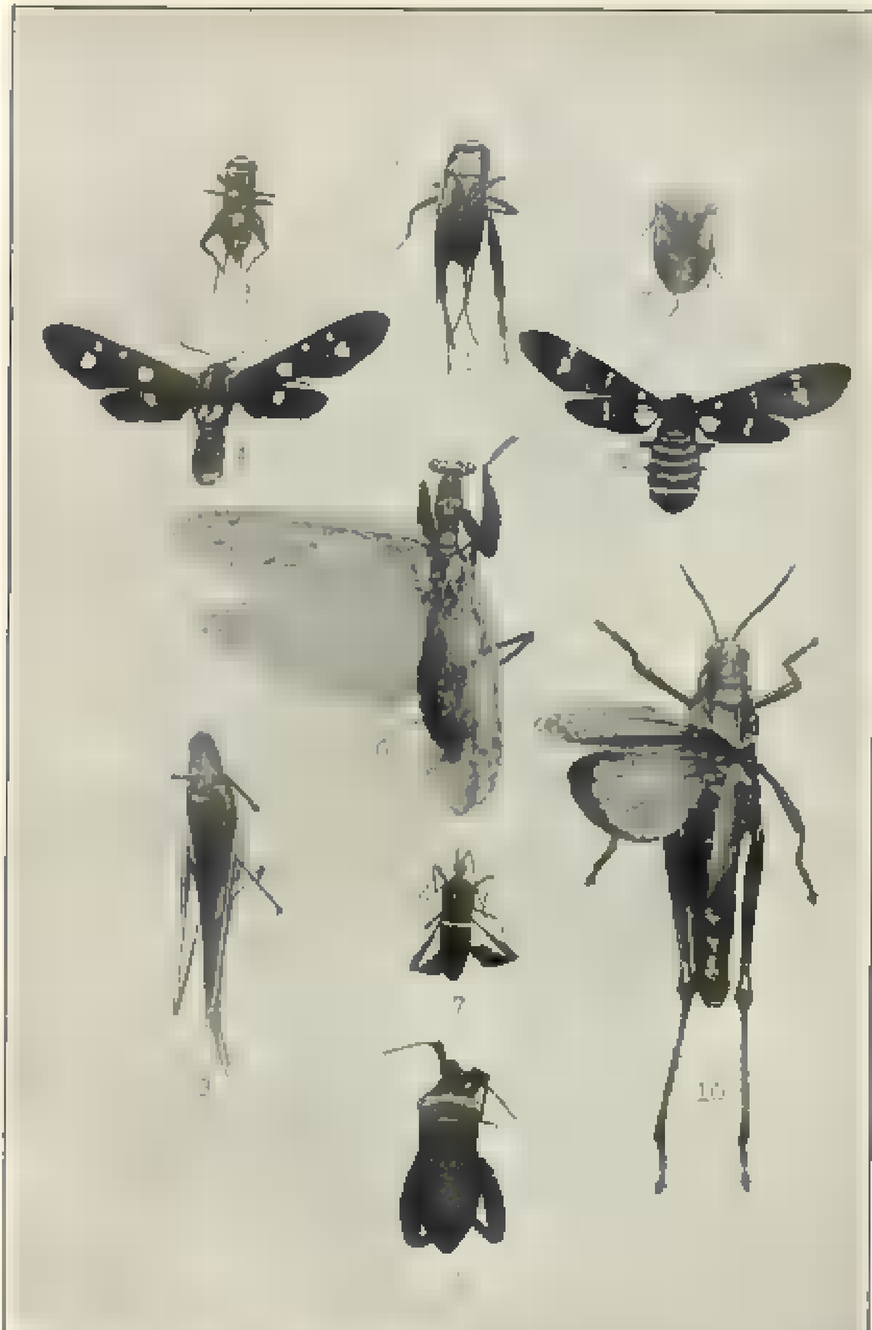
GROUND-PEARLS, MARGARODES FORMICARUM, FROM PARADISE KEY.

Enlarged 6 diameters. Collected by C. E. Mosier.



STRINGS OF GROUND-PEARLS, MARGARODES FORMICARUM, DISCOLORED BY AGE, SURROUNDING FRESHER SPECIMENS OF A GOLDEN COLOR.

Collected by C. V. Riley and H. G. Hubbard in the West Indies. Natural size. Photograph received from Dr. L. O. Howard.



INSECTS OF PARADISE KEY.

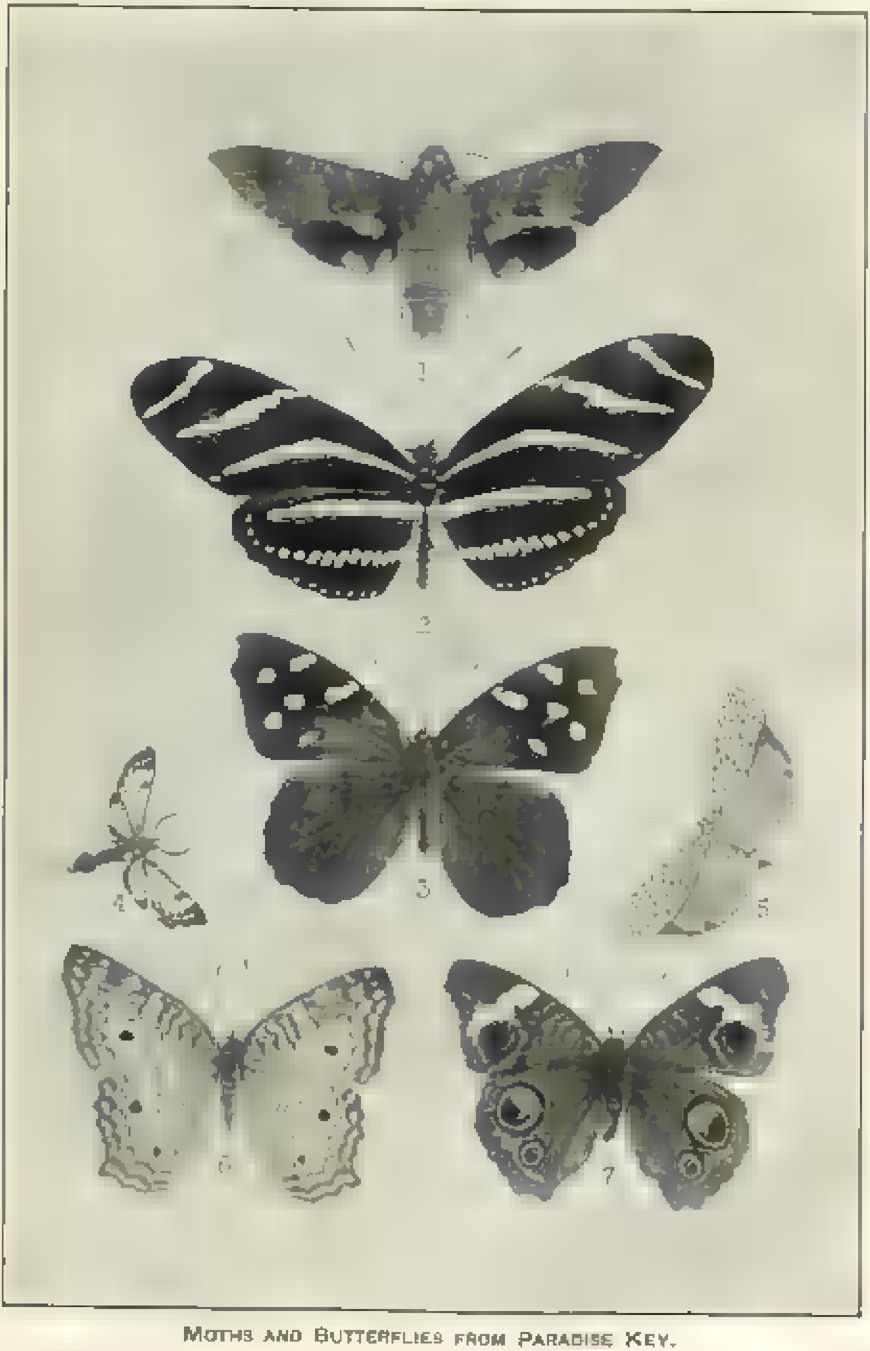
1, House Cricket (*Gryllus assimilis*), female; 2, Male of same species; 3, *[illegible]*; 4, Polka-dot Wasp Moth (*Syntomeida epilais*); 5, Orange-banded Wasp Moth (*Syntomeida ipomoeae*); 6, Southern Mantis (*Gonatista grisea*); 7, Leaf-foot Plant Bug (*Leptoglossus phyllopus*); 8, Big-thigh Plant Bug (*Metapodius femoratus*); 9, Katydid (*Scudderia texensis*); 10, Grasshopper (*Romalea microptera*), male. Natural size.

INSECTS OF PARADISE KEY.

1, Water-lily moth (*Xanthopastis timais*); 2, Same with wings folded; 3, Giant horsefly (*Tabanus americanus*); 4, Giant grasshopper (*Romalea microptera*); 5, Palmetto weevil (*Rhynchophorus cruentatus*); 6, Roach (*Eurycotis ingens*); 7, [illegible] weevil (*Brentus anchorago*); Zamia butterfly (*Eumaeus atala*); 9, Cycas butterfly (*Eumaeus minyas*). Natural size.

SCALE OF A BUTTERFLY'S WING (PAPILIO SP.) MAGNIFIED 750 DIAMETERS.

Photograph by Raymond Thrasher.



MOTHS AND BUTTERFLIES FROM PARADISE KEY.

1, *Perigonia lusca interrupta*; 2, *Heliconius charitonius*; 3, *Eunica tatila*; 4, *Didasys belae*; 5, *Utetheisa bella*; 6, *Anartia jatrophae*; 7, *Junonia coenia*. Natural size.

REGAL BUTTERFLIES FROM PARADISE KEY.

1, The Queen, *Anosia berenice*; 2, The Monarch, *Anosia plexippus*; 3, The Florida Viceroy, *Basilarchia floridensis*. Natural size.

BUTTERFLIES OF PARADISE KEY.

1, *Dione (Agraulis) vanillae*; 2, *Catopsilia eubule*, male; 3, *Anaea (Pyrrhanaea) portia*; 4, *Catopsilia agarithe maxima*; 5, *Catopsilia eubule*, female. Natural size.

BUTTERFLIES OF PARADISE KEY.

1, *Eudamus proteus;* 2, *Papilio cresphontes;* 3, *Eurema* (*Terias*) *euterpe;* 4, *Papilio palamedes.*

HYMENOPTERA OF PARADISE KEY.

1, *Xylocopa micans*; 2, *Camponotus abdominalis floridanus*; 3, *Hypocrabro decemmaculatus*; 4, *Megachile pollicaris*, a leafcutter; 5, *Pristaulacus floridanus*; 6, *Coelioxys dolichos*, a cuckoo bee; 7, *Campsomeris quadrimaculata*; 8, 9, 10, *Bombus pennsylvanicus*, worker, male, and queen; 11, Nest of potter wasp (*Eumenes*); 12, Jewel wasps (*Chrysidids*) found in potter's nests; 13, Jewel wasp, *Trichrysis parvula*. Natural size.

JEWEL WASPS (TRICHRYSIS PARVULA) FOUND IN NESTS OF POTTER WASP (EUMENES), WHICH THEY ENTER TO DEPOSIT THEIR EGGS.

The upper one is rolled up like an armadillo for self-protection. Enlarged [illegible] diameters.

DIPTERA OF PARADISE KEY.

1, Flower fly, *Ocyptamus [illegible]*; 2, Horsefly, *Tabanus trijunctus*; 3, Flower fly, *Eristalis [illegible]*; 4, Flower fly, *[illegible]*; 5, Midas fly, *Mydas clavatus*; 6, Deer fly, *Chrysops flavidus*; 7, Screw-worm fly, *Chrysomya macellaria*; 8, Tachina fly, *Archytas hystrix*; 9, Soldier fly, *Hermetia illucens*. Natural size.

Roseate Spoonbill—fast disappearing from the Everglades

PREHISTORIC TERRACE MADE OF CONCH SHELLS (FULGUR (BUSYCON) PERVERSUM) BY ABORIGINAL INDIANS OF SOUTHERN FLORIDA.

Similar shells are found in burial mounds of the Mississippi Valley and its tributaries. Photograph by Frank Hamilton Cushing.

LADLE MADE FROM SHELL OF FULGUR (BUSYCON) PERVERSUM, USED BY ABORIGINAL INDIANS OF SOUTHERN FLORIDA.

Photograph of specimen in United States National Museum. About two-thirds natural size.

"SEASIDE GRAPES" (COCCOLOBIS UVIFERA), A FOOD-STAPLE OF THE ABORIGINAL INDIANS OF SOUTHERN FLORIDA.

FRUIT OF THE DWARF SAW PALMETTO (SERENOA SERRULATA), MUCH RELISHED BY THE ABORIGINAL INDIANS OF SOUTHERN FLORIDA IN SPITE OF ITS ACRID RANCID TASTE.

LEAVES OF ILEX VOMITORIA, USED BY THE ABORIGINAL INDIANS OF FLORIDA FOR MAKING THEIR CEREMONIAL "BLACK DRINK."

LIVE OAK (QUERCUS VIRGINIANA) FROM ROYAL PALM STATE PARK.

The acorns were used in early times as a food staple. The Spaniards sometimes used them for making a chocolate-like drink.

SEMINOLE INDIAN BOYS POLING A CANOE IN AN EVERGLADE SLOUGH.

Photograph by Julian A. Dimock.

SEMINOLE INDIAN OF THE EVERGLADES OF FLORIDA AND HIS SON.

Photograph by Julian A. Dimock. The Seminoles are related to the Creeks and Choctaws.

ROOTS OF A CYCAD, ZAMIA FLORIDANA, FROM WHICH THE INDIANS PREPARED THEIR EDIBLE "COONTIE" (FLORIDA ARROWROOT).

Photograph of specimens obtained from the arrowroot factory of Mr. Hurst, near Miami.

TUBEROUS ROOTS OF SMILAX AURICULATA, THE SOURCE OF THE "RED COONTIE" OF THE SOUTHERN INDIANS.

Photograph of specimens collected near Miami by William Marmick. Natural size.

NOTES ON THE EARLY HISTORY OF THE PECAN IN AMERICA.

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While engaged in studying certain features of the early days of American botanical activity I have found many references to the history of what is perhaps America's most important contribution to the world's stock of edible nuts, the pecan; and since the sources in some cases are unpublished manuscripts and in others old or rare works not easy of access, I have here brought together the accumulation of somewhat scattered notes. They are bound together by the fact that they shed light on the early history of this important native tree, and in some cases on the interesting part played by one of our great statesmen in gaining and disseminating information concerning it. No claim to completeness is made for this somewhat desultory study.

DISCOVERY BY THE SPANIARDS.[1]

There seems to be no reason to doubt that the natives living along the lower courses of the Ohio and the Mississippi Rivers and their tributaries, as well as those occupying eastern and central Texas, draining into the Gulf of Mexico, knew and esteemed the pecan as an acceptable article of food long before the white man visited the continent. The discovery by the whites, therefore, merely made the existence and characteristics of the plant matters of record for our race and therefore of so-called history. Among the accounts written by explorers traversing the regions to which the pecan is indigenous, the earliest seen which mentions this tree was the narrative of Cabeça de Vaca. That unlucky Spaniard, between 1528 and 1543, with the Indians who had enslaved him, traversed the coastal strip of Texas from Galveston Island to the Guadalupe River and beyond. In the story of his wanderings which extended far to the west and south occur the following sentences:

> Two days after Lope de Oviedo left, the Indians * * * came to the place of which we had been told, to eat walnuts. These are ground with a kind of small grain, and this is the subsistence of the people two months in

[1] For valuable suggestions concerning early Spanish explorers I am indebted to Prof. Herbert E. Bolton, of the University of California, Berkeley, Cal., and to Dr. James A. Robertson, of the Carnegie Institution of Washington, District of Columbia.

the year without any other thing; but even the nuts they do not have every season, as the tree produces in alternate years. The fruit is the size of that in Galicia [Spain], the trees are very large and numerous.[1]

Oviedo's account of the same place says:

There were on the banks (en las costas) of the river many nuts, which the Indians ate in their season, coming from twenty or thirty leagues round about. These nuts were much smaller than those of Spain.[2]

The location of this river of nuts has been the matter of considerable investigation by Baskett, who decides that it was the Guadalupe, somewhere in its lower course. The time is given by Hodge as the year 1533.

In view of the wide distribution along the wooded bottom lands, bordering the lower course of most of the rivers of middle and eastern Texas, of several species of trees related to the walnuts, one can hardly state with certainty what kind is here concerned. However, the habitat, the great size of the tree, the edible quality, and the size of the nuts (in case Oviedo was right) would strongly suggest that the accounts here refer to one of the many pecan groves which occur in localities like that here described.

The problem faced by the translator of Spanish annals is an important one for us, since Texas was visited for centuries by Spaniards who left accounts of their travels, and scholars wishing to render these stories into accurate English usage have to decide what to call the nuts there mentioned. Some have adhered to the philological aspect of the matter and in translating the words *nueces* and *nogales* have used the terms *nuts* and *walnuts*, while others have adopted the word *pecan* as the probable modern name of the trees discussed. The latter course involves a botanical as well as a philological judgment and might lead to error if incorrectly employed. It seems to me, however, highly probable that the tree seen by Cabeça and Oviedo on the banks of the Guadalupe in 1533 was the pecan as certain translators have regarded it.

At a somewhat later date, Hernando de Soto entered the pecan area from the north and east. Between 1539 and 1542 he traversed the southeastern part of the present United States. An English translation of his account is included in that treasury of adventure, Hakluytus Posthumus or Purchas his Pilgrimes contayning a History of the World in Sea Voyages and Lande Travells by Englishmen and others.[3]

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[1] Hodge, Frederick W., Spanish Explorers in the Southern United States, 1528–1543. The Narrative of Alvar Nuñez Cabeça de Vaca. Scribner's Sons. 1907 : 69.

[2] Baskett, James Newton, A Study of the Route of Cabeza de Vaca. Texas Hist. Assoc. Quart., 10 : 253. 1906–7.

[3] In the excellent edition published by James MacLehose and Sons, Glasgow, 1906, in 20 volumes, the account of De Soto's wanderings in America is found in volumes 17 : 521–548 and 18 : 1–51.

In the early stages of his exploration (v. 18:3) De Soto reports finding at an Indian town called *Chiaha*, supposed to be near the present site of Columbus, Georgia, on the Chattahooche River,[1] a great store of oil of walnuts clear as butter and of a good taste. This place is outside of the recognized range of the pecan in its wild state, and the term *walnut* used by the translator must here refer to some other plant. Mr. James Mooney, of the Bureau of Ethnology, informs me that this was the hickory-nut oil, still used by the Cherokees of the same region as formerly by the Creeks. As De Soto progresses northward and farther to the west, in the country of the chief called Casqui, he finds walnuts in great number of a new type bearing soft-shelled nuts in form like bullets, which the Indians had laid up in great store in their houses. The trees differed from those of Spain and from those seen before in America only by the smaller leaf. The location of the country of Casqui is perhaps somewhat doubtful. Thomas Nuttall, in the appendix to his Journal of Travels,[2] identified this region with that known to the French as Kaskaskia, a point on the Mississippi River near the mouth of the Kaskaskia River in Illinois, and he sought to identify the stores of nuts referred to with the pecans abundant in the lowlands along the watercourses, especially to the southward. A more recent interpretation of De Soto's localities (Shepherd, Historical Atlas, 1911:191) would place the most northerly point reached by him in about the latitude of Memphis, and would thus seem to locate this abundant occurrence of pecans considerably farther to the south. Nuttall indicates his opinion that De Soto's description of the nuts and of the tree must refer to the pecan, a conclusion that will hardly be questioned.

De Soto again mentions walnuts in great store, probably pecans, at Autiamque, where he spent a winter (18:34), this locality probably lying in southern Arkansas on the Washita River. They were also reported at a place named Nilco, probably in northern Louisiana, roughly west of the mouth of the Yazoo River. These points are all well within the range of the pecan.[3]

Fortunately the accounts left by several later Spanish travelers with whom we are concerned in this connection have been edited in English by Prof. Herbert E. Bolton, professor of American history at the University of California.[4] Among those who entered the region of the pecan in Texas were Mendoza and De Léon. In 1683-

[1] Mooney, James, Myths of the Cherokee. Nineteenth Annual Report, Bureau American Ethnology. Pt. 1:199. 1900.

[2] Nuttall, Thomas. A Journal of Travels in the Arkansas Territory During the Year 1819, with Occasional Observations on the Manners of the Aborigines. Philadelphia. 1821:232.

[3] Reed, C. A., Pecan culture; with special reference to propagation and varieties. Farmers' Bulletin 700, U. S. Dept. Agr. 1916:3.

[4] Bolton, Herbert E., Original Narratives of Early American History. Spanish Exploration in the Southwest. 1542–1706. Charles Scribner's Sons, New York. 1916.

84, Mendoza traversed the region of the middle Concho River to its junction with the Nueces and farther eastward to the Colorado River near its junction with the main Concho River. He mentions seeing walnut trees (nogales) which Professor Bolton thinks were in all probability pecans, and which he calls such in his translation. These trees are described as occurring along watercourses (p. 334) "the bottoms have many groves of them." In another place "were several great groves of very tall pecan and live oak trees" (p. 335). Many other references to these luxuriant growths occur in this account.

De León, who visited Texas in 1689 on his march into Texas from Mexico, refers repeatedly to some form of walnut (nogales) called in the translation *pecans*.[1] The Nueces River, Atascosa Creek, and Medina River are identified by Miss West[2] among the streams said by De León to be bordered by pecans, frequently accompanied by oaks, and sometimes by grapevines (p. 209). Miss West also renders *nogal* as *pecan*, which was probably the predominant species seen by the explorer.

To follow the pecan through early Spanish literature would lead us beyond the limits of these notes. One other Spanish explorer, who came at a much later date and who penetrated into the river valleys tributary to the Mississippi, must, however, be referred to in connection with the discussion of another phase of pecan history.

DISCOVERY BY THE FRENCH.

It would be expected that the later exploration and exploitation of the pecan country, a large part of which was covered by the early territorial claims of the French, would have produced important additions to the information given by De Soto. A thorough canvass of the accounts of the early French voyageurs has not been attempted but a number of early references to the pecan have come to my attention.[3]

It is highly probable that La Salle and other explorers of the lower Mississippi and of its tributaries encountered the pecan. So abundant and so acceptable a food product could hardly have been neglected by travelers finding it when ripe. The earliest reference seen, however, is by Pénicaut, who, in 1704, proceeding from the south where the main expedition under De Bienville had entered the mouth of the Mississippi, ascended to the village of Natchez. He devoted a chapter in his account of this journey to a description of the place, its inhabitants, and its products. As reprinted in his old-time French he gives, perhaps, the earliest French description of the

[1] Bolton, H. E. Ibid., pp. 391, 393.

[2] West, Elizabeth Howard. De León's Expedition of 1689. An annotated translation. Quart. Texas State Hist. Assoc. 8: 199–224. 1905.

[3] I am indebted to Dr. C. S. Sargent of the Arnold Arboretum for helpful suggestions in connection with certain of the early French explorations.

pecan.[1] In addition to the few words of description he mentions the common name used by the natives:

> Ils sont de trois sortes de noyers: il y en a dont les noix sont grosses comme le poing, et qui servent à faire du pain pour leur soupe, mais les meilleures ne sont guères plus grosses que le poulce;[2] ils les appellent pecanes.[3]

While it must be admitted that there is little said to distinguish the nut, the high quality mentioned in connection with the characteristic name seems to point to that now known as the pecan.

Another somewhat later reference based on trees seen in the northern part of the range is made by the Jesuit missionary, Father Gabriel Marest, who in writing to Father Germon, of the same order, from "Cascaskias, an Illinois village," on November 9, 1712, observes that "there are different kinds of nut trees. The pecans (Les pacanes) (it is thus that the fruits of one of the nut trees is called) have a better flavor than our nuts in France."[4]

Unless we assume that the name *pacane* was applied with accuracy to this very distinct type of nut, there is but little basis for an assertion that Marest had in mind the pecan as we understand it. On the other hand, the location and the flavor of the nut would seem to favor the presumption of accuracy.

The situation is somewhat clearer with Charlevoix. In an entry made in his Journal on October 20, 1721, likewise at "Kaskasquias," he observes:

> Parmi les Fruitiers, qui sont particuliers à ce Pays, les plus remarquables sont les Pacaniers * * * Le Pacane est une Noix de la longueur & de la figure d'un gros Gland. Il y en a, dont la coque est fort mince * * * Toutes sont d'un goût fin & délicat. l'Arbre qui les porte, vient fort haut: son bois, son écorce, l'odeur & la figure de ses feuilles m'ont paru assez semblables aux *Noyers d'Europe*.[5]

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[1] Pénicaut's Relation in Découvertes et Établissements des Français dans l'Ouest et dans le Sud de l'Amérique septentrionale. (1614–1754.) Mémoires et Documents originaux recueillis et publiés par Pierre Margry, etc. Première Formation d'une Chaîne de Postes entre le Fleuve Saint-Laurent et le Golfe du Mexique (1683–1724). Tome V: 445. Paris, 1883.

[2] "Poulce," an old form of "pouce," meaning the thumb, as indicated in Hatzfeld and Darmesteter (Dictionnaire générale de la Langue française, II: 1764), probably gives the measure of the size. As an old measure of length it equals the twelfth part of the old French foot, or, roughly, a modern inch.

[3] There are three sorts of walnuts. There are some with nuts as large as the fist, and which serve in making bread for their soup, but the best are not larger than the thumb; they call them pecans.

[4] Thwaites, R. G., The Jesuit Relations and Allied Documents. 66: 229.

[5] Charlevoix, P. F., Journal d'un Voyage fait par ordre du roi dans l'Amérique septentrionale; adressé à Madame la Duchesse de Lesdiguières, constituting vols. 5 and 6 of Histoire et description générale de la Nouvelle France, &c. Paris, 1744. T. 6: 140, Lettre XXVIII.

Among the fruits that are peculiar to this country the most remarkable are the pecans. * * * The pecan is a nut having the length and form of a large acorn. There are those with a very thin shell. * * * All have a fine and delicate taste; the tree which bears them grows very high; its wood, its bark, the odor, and the shape of the leaves appear to me similar enough to the walnuts of Europe.

It would seem clear that Charlevoix is here referring to a considerable number of forms and without much doubt includes in the term *Pacane* one or more types of hickory nut with the *pecan* as we now use the term.

While describing in his General History the adventures of La Salle near the mouth of the Mississippi River in 1685, Charlevoix seems to indicate that he might have found this nut. A form of walnut described as "larger than the ordinary ones" and "very good" is regarded by his translator, Shea, as the pecan.[1] The evidence here is so incomplete, however, as to leave room for doubt on this point, although the guess may perhaps be correct.

At a somewhat later date Le Page du Pratz[2] described the Louisiana country, and in discussing the various nuts growing in that province writes:

> Il y a encore les Pacaniers dont le fruit est une espèce de noix fort petite, & qu'on prendroit au coup d'oeil pour des noisettes, parcequ' elles en ont la forme, la couleur, & la coque aussi tendre; mais en dedans elles sont figurées comme les noix: elles sont plus délicates que les nôtres, moins huileuses & d'un goût si fin, que les François en ont des pralines aussi bonnes que celles d'amandes.[3]

The translator responsible for the wording of the English edition of 1763[4] translates *Pacaniers* as *Hicori*, no mention of the pecan coming to my attention in any other place. That this historian or any other observer traveling through the lowlands bordering the lower Mississippi or those of its tributaries would be likely to miss the pecan seems to me very unlikely.

INTRODUCTION INTO THE EAST.

Concerning the introduction of the pecan to European civilization, the writer has seen nothing to indicate that either the early Spanish or the early French explorers accomplished this. However, it is probable that the pecan was cultivated in Spain perhaps before it was grown either in France or in England. The pecan seems to have first become known in the English colonies in 1761, through the botanist John Bartram, of Philadelphia.[5]

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[1] Charlevoix, The Rev. P. F. X., History and general description of New France. Translated with notes by John Gilmary Shea, in 6 volumes. New York. Vol. 4, 1870, p. 72.

[2] Du Pratz, Le Page, Histoire de la Louisiane. Paris, 1758. T. II: 26.

[3] There are again the pecans the fruit of which is a kind of very small walnut that would be taken at first glance for a filbert, since they have the form, the outline, and the likewise thin shell, but internally they are shaped like the walnut; they are more delicate than our own, less oily, and with a flavor so fine that the French make "pralines" (a kind of baked cake composed of almonds) of them as good as those made of almonds.

[4] Du Pratz, Le Page. The history of Louisiana. 2 vols. Becket & De Hondt. London. 1763. Vol. 2: 21.

[5] Darlington, Wm., Memorials of John Bartram and Humphry Marshall, Philadelphia, 1849: 251.

On August 14, 1761, Bartram writes to his botanical friend and correspondent in London, Peter Collinson (p. 232):

I have not yet been at the Ohio, but have many specimens from there. But in about two weeks I hope to set out to search myself, if the barbarous Indians don't hinder me (and if I die a martyr to botany, God's will be done; His will be done in all things) * * *.

It will be recalled that at this time the French and Indian War was in progress, the English under the lead of General Forbes and Colonel Bouquet having captured Fort Duquesne about two years before and named it Fort Pitt or Pittsburgh. Thither Bartram seems to have gone, probably near the date assigned, and from thence safely returned, since on December 12, 1761, he seems to have sent a box of plants and seeds to Collinson which provoked from the latter the following sportive comment, dated at London, April 1, 1762:

I really believe my honest John is a *great wag*, and has sent me seven hard, stony seeds, something shaped like an acorn, to puzzle us; for there is no name to them. I have a vast collection of seeds, but none like them. I do laugh at Gordon, for he guesses them to be a species of Hickory * * *. I think they may be what I wish, seeds of the Bonduc Tree *Gymnocladus canadensis* Lam. which thou picked up in thy rambles on the Ohio.

A footnote, probably by the author of the memoirs, states:

Gordon made decidedly the best *guess*, for these "stony seeds" were no doubt the nuts of the *Pecan or Illinois Hickory* (*Carya olivaeformis*, Nutt.).

In reply to Peter's remarks, John Bartram says:

The hard nuts I sent were given me at Pittsburgh by Colonel Bouquet. He called them Hickory nuts. He had them from the country of the Illinois. Their kernel was very sweet. I am afraid they won't sprout, as being a year old. (P. 233.)

Thus the nuts obtained by Bartram in September, perhaps, 1761, were seen in England very early in 1762.

A letter from John St. Clair to John Bartram locates even more accurately the date of his visit to Pittsburgh and the date of his receipt of the pecans. This letter is written at Belville, November 4, 1761, and says in part:

I congratulate you on your safe arrival from Pittsburgh * * *. I give you many thanks for the valuable (Pecan) Hickory nuts. I should have thanked you sooner for them, but I waited to see if I was to go on the expedition (to Africa) that is fitting out.

It is probable that Belville was at the end of no long journey from the home of Bartram, since St. Clair closes his note by saying:

If you will send anybody to this place to bring a cow for Mrs. Bartram, she will oblige me in accepting of her.

It may, therefore, be assumed that little time was lost in transit either by the nuts in going to St. Clair or by his acknowledgment of

them when once started for Philadelphia. Making these assumptions, it seems probable that Bartram returned with the nuts some time in October, 1761.

This chronology implies a different and earlier introduction from that referred to by Brendel,[1] who says that the tree "was unknown to the English colonies until the peace of 1762 (sic), where by chance some fur traders brought a small number of nuts to New York." If the fur traders here referred to waited until peace was signed, they could hardly have come to New York until the following year, the treaty of Paris being dated February, 1763. The account given by Brendel is followed by Sargent,[2] who in turn is quoted by Heiges.[3]

It will be noted that thus far the nut was known to the Colonies only from the northern portion of its range, along the Ohio River, Illinois River, and in general from what was vaguely known as the Illinois country.

The southern range seems not to have become known until some years later. The Spanish traveler and writer, Don Antonio de Ulloa, in traversing the region drained by the lower tributaries of the Mississippi, describes the trees of the region and gives a description fuller than any earlier one that has come to my attention. Mr. W. E. Safford, of the Department of Agriculture, has kindly translated Ulloa's statement.[4]

> Two other kinds of trees are found there which appear to be peculiar to that country. One of these they call *Pecanos*, which is a kind of walnut of greater body than those (walnuts), but in wood and leaf very similar. The fruit is in taste similar to that of the walnut, more delicate and finer, with less proportion of oil. In form it is different, and resembles dates, being in size almost the same or a little less. The shell is thin and smooth and without the roughness which the walnut has.

This account not only points out another part of the wide area occupied by this tree but repeats the native name used in 1712 by Marest for the nut found in Illinois, the name that in a modified form has established itself in general usage.

Perhaps the first actual introduction of the pecan into the East from the South took place late in 1799, when Daniel Clark, jr., of New Orleans, at that time still Spanish territory, sent a box of nuts to Thomas Jefferson, then Vice President of the United States, at Philadelphia. Clark wrote:

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[1] Brendel, Frederick, Historical sketch of the science of botany in North America, from 1635 to 1840. American Naturalist, 13: 757, 1879.

[2] Sargent, Charles Sprague, The Silva of North America. VII: 140.

[3] Heiges, S. B., Nut culture in the United States, embracing native and introduced species. Division of Pomology, U. S. Dept. of Agriculture. 1896: 56.

[4] Ulloa, Antonio de, Noticias Americanas; Entretenimientos physico-historicos sobre la América meridional, y la Septentrional oriental, &c. Madrid. 1772: 116–117. Entretenimiento VI.

New Orleans, 12 November, 1799.[1]

Sir, As the country produces excellent oranges, I have presumed to send to the care of Mr. Daniel W. Coxe of Philadelphia a barrel hand picked & well put [up] to be delivered to you and a box of Paccan nuts. these last are not I understand common in the Atlantic Parts of the U. S. tho' they grow everywhere on the Banks of the Mississippi from the Illinois River to the Sea, generally in the low grounds and even in places occasionally overflowed by the annual rise of the waters, the Tree grows to the usual size of the Forest Trees and affords a delightful shade in Summer. It might be worth while to cultivate it in Virginia for use & ornament. I propose to send you shortly by way of Baltimore if no opportunity offers direct for Virginia a Bag of a superior kind which I am promised by a Friend and will occasionally take the liberty of sending you anything which I may suppose either rare or curious with you that I can procure here.

Jefferson's reply was not seen, but another letter from Clark to the Vice President, written May 20, 1800, seems to tell at least part of the story.

I am happy to learn that the few Pacans I sent are likely to turn to such good account, and sincerely wish your Grove of them may flourish.[2] * * *

Jefferson's reply to this letter was also not seen, but again Clark gives us a clue to a part of its contents, in a letter written July 20, 1801, when he recurs to the subject:[3]

In the last letter I had the honor of receiving from you you mention that your Pacan Trees at Monticello tho planted in 1780 had not hitherto born (sic) fruit. This must be owing to their being planted in too elevated or too dry a soil as they bear in this Country in ten or twelve years, and the trees in their natural State are I believe always found in the River Bottoms and in places occasionally overflowed at the annual rise of the Rivers. I have taken the liberty of mentioning this Circumstance that you may try the Experiment on some young Trees I send herewith put up in a Case as well as a few Orange Trees which I hope will get safe to hand.

BOTANICAL DESCRIPTION.

The only information about the pecan available for many years was substantially of the type that could be gained from travelers' notes, and while these often designated the plant with sufficient clearness to enable the informed reader to know what the writers had in mind, it could not be said that a botanical description of the plant had been made. This seems to have been done first by Thomas Jefferson in his Notes on Virginia, written in 1781 and printed in Paris under date of 1782:[4]

Paccan or Illinois nut. Not described by Linnaeus, Miller or Clayton. Were I to venture to describe this, speaking of the fruit from memory, and of

[1] Jefferson Papers, Manuscripts Division, Library of Congress, S. 2, vol. 10, No. 00.

[2] Jefferson Papers, Ser. 2, vol. 10, No. 22. Manuscripts Division, Library of Congress.

[3] Jefferson Papers, Ser. 2, vol. 10, No. 23. Manuscripts Division, Library of Congress.

[4] Jefferson, Thomas, Notes on the State of Virginia written in the year 1781, somewhat corrected and enlarged in the winter of 1782, for the use of a Foreigner of distinction, in answer to certain queries proposed by him. Paris, 1782: 04.

the leaf from plants of two years' growth, I should specify it as the *Juglans alba*, foliolis lanceolatis, acuminatis, serratis, tomentosis, fructu minore, ovato, compresso, vix insculpto, dulci, putamine tenerrimo. It grows on the Illinois, Wabash, Ohio and Mississippi. It is spoken of by Don Ulloa under the name of pacanos, in his Noticias Americanas, Entret. 6.

Not long after Jefferson's description had appeared, Dr. Humphry Marshall, of Philadelphia, brought out his little book entitled Arbustrum Americanum,[1] in which he refers very vaguely and inaccurately to the pecan under the binomial *Juglans pecan*, "the Pecan, or Illinois Hickery." The range noted is limited to the Illinois country, probably indicating that he drew his information from travelers who knew of the tree in its northern range only. The description does not suffice to clothe the name proposed by him, and, in my judgment, the earlier and more accurate Latin diagnosis of Jefferson should occupy the first place in the nomenclatorial history of this plant.

THE NAME PECAN.

It may perhaps not be out of place to refer briefly to the variety of common names by which this nut has been known. It seems to have been referred to by early Spanish explorers in Texas under the general term *nueces*, meaning *nuts*, or by the more specific term *nogales*, meaning *walnuts*. There seems to be no evidence that the Indians in that part of the country designated these nuts by any characteristic term, nothing to suggest the word *pecan* or any of its modifications. The French explorers, Father Marest (1712), at the northern edge of the pecan range, and Pénicaut (1701), at Natchez, independently fell to using the term *pacane*, the native name found in use by both of them. Later French writers, in describing the Mississippi Valley or its tributaries, mention the *pecane*. Ulloa, publishing his explorations in the Mississippi Valley in 1772, unlike his earlier compatriots, mentions this same name under the Spanish guise *pacanos*. This evidence seems to indicate that the term *pecane* or some modification of it was the name used probably from time immemorial by the Indian tribes along the Mississippi and its tributaries. This term was probably not used by the tribes living to the westward in the country drained by the rivers which directly flow into the Gulf.

The terms "Illinois nut" or "Illinois hickory" were probably given by the colonists of the East, in ignorance of the Indian name that had found acceptance and use in the Mississippi Valley by French and Spanish from Kaskaskia to the Gulf. Probably the term "Mississippi Nut," by which George Washington designated it in an

[1] Marshall, Humphry. Arbustrum Americanum: The American Grove or an alphabetical catalogue of the forest trees and shrubs, native to the American United States, arranged according to the Linnaean system, etc. Philadelphia. 1785 : 69.

entry in his diary for March 11, 1775, was given in much the same way. In 1786 he uses the name "Illinois nut" and in 1794 approaches the Indian name in the term "Poccon"[1] or Illinois nut. An interesting persistence of the old Indian name was in use as late as 1833 by Kenrick, who refers to the tree as the "pacane nut."[2]

INTRODUCTION INTO EUROPE.

As far as the writer has learned, the first sending of the pecan to Europe consisted of the nuts sent to England, probably in January, 1761, by John Bartram, which so much puzzled Peter Collinson.

Thomas Jefferson seems to have performed the same service in France about 25 years later. In 1786, while living in Paris as American representative, he procured a small package of these nuts through Francis Hopkinson, of Philadelphia. Their correspondence on this matter is here sketched. Writing from Paris on January 3, 1786, Jefferson makes several requests of Hopkinson.

> The third commission is more distant. It is to procure me two or three hundred paccan-nuts from the western country. I expect they can always be got at Pittsburgh, and am in hopes, that by yourself or your friends, some attentive person there may be engaged to send them to you. They should come as fresh as possible, and come best, I believe, in a box of sand. Of this Bartram could best advise you * * *.[3]

Hopkinson seems to have been in doubt concerning the identity of the nut going under the name given by Jefferson. In answer to his inquiry, Jefferson replied from Paris on December 23, 1786:

> The paccan-nut is, as you conjecture, the Illinois nut. The former is the vulgar name south of the Potomac, as also with the Indians and Spaniards, and enters also into the Botanical name, which is *Juglans Paccan.*[4]

This information seems to have satisfied Hopkinson who probably procured the desired nuts. At all events, among the uncatalogued Jefferson manuscripts in the Library of Congress is a letter addressed to Wilt Delmestre & Cie, from Paris, July 13, 1787, in which the writer directs that "a box of paccan nuts" be nailed up and sent by diligence and without delay at local customs houses en route. These instructions to this firm were designed to bring the nuts with all speed from the port of landing to Paris. I am unable to say who received these nuts and what the recipients may have done with them. It is quite probable from the mode of packing specified that they were wanted for planting and some may well have found their way to

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[1] Haworth, Paul L., George Washington Farmer. Indianapolis. P. 160.

[2] Kenrick, William, The New American Orchardist, or an account of the most valuable varieties of fruit, adapted to cultivation in the climate of the United States from the latitude of 25° to 45°, etc. Boston. 1833: 859.

[3] Jefferson, Thomas, The writings of. By Thomas Jefferson Memorial Association, Washington, D. C., in 20 volumes. 1904. Vol. 5: 242.

[4] Ibid. Vol. 6: 21.

Jefferson's good friend, Thouin, the director of the Jardin des Plantes in Paris.

EARLY CULTIVATION IN AMERICA.

It is perhaps impossible to state the date of the first planting of this nut in America, and perhaps equally difficult to ascertain who made it. It seems quite possible, however, that the oldest cultivated trees are to be found in Mexico. Onderdonk[1] in 1911 reports seeing pecans growing on irrigated lands at Bustamente, 100 miles beyond Laredo, Texas, which he estimated to have reached an age of 200 years. This far antedates all known plantings in the Colonies of the Atlantic coast.

Among the eastern Colonies precedence seems to belong to New York. According to Brendel,[2] William Prince in 1772 planted 30 nuts in his nursery at Flushing, Long Island, raising 10 plants; 8 going to England at 10 guineas apiece, 2 being kept for reproduction.

The planting made by Prince did not long anticipate one made by William Hamilton, proprietor of the famous gardens near Philadelphia, known as the Woodlands. Hamilton, writing to Humphry Marshall, who described this tree so badly, says in a letter dated "The Woodlands, May 3d, 1799,"[3] referring to the disastrous effects of a recent heavy frost:

> A tree, too, the only one I had of *Juglans Pecane*, or Illinois Hickory, which I raised twenty-five years ago from seed, is entirely killed.

The date of planting of this tree would have been in 1774.

It is well known that George Washington was an enthusiastic grower of interesting and novel plants, maintaining a special plot of ground for experimental purposes which he often refers to in his diary as "the Botanical Garden." In an entry for March 11, 1775, without doubt describing his planting operations for the day, he writes:

> Row next these (white peaches from Phila.) 25 Mississippi Nuts—something like the Fig nut—but longer, thinner shelld and fuller of meat.[4]

This was probably his first planting, since he takes the trouble to describe the nut. This was followed in 1786 by a second record. On—

> Wednesday, 24 (May, 1786). planted 140 seed sent me by Colo. Wm. Washington and said by him to be the seed of the large magnolia or Laurel of

[1] Onderdonk, Gilbert, Pomological Possibilities of Texas. Bull. 18, Texas Department of Agriculture, Austin, Tex. 1911: 46. Revised edition.

[2] Brendel, Frederick, American Naturalist, 13: 757, 1879. Quoted by Sargent, C. S., in Silva of North America, VII: 140; also by Heiges, S. B., Nut Culture in the United States. Div. Pomology, U. S. Dept. Agriculture, 1896: 60.

[3] Darlington, William, Memorials of John Bartram and Humphry Marshall, 1849: 580.

[4] Diary of George Washington. J. M. Toner transcript. Vol. 13: 928. In Manuscripts Division, Library of Congress, Washington, D. C.

Carolina * * * Also 21 of the Illinois Nuts; completing at the No. end; the piece of a Row in my Botanical Garden in which on the — day of — I put Gloucester hiccory Nuts.[2]

We note that Jefferson's description of the plant written in 1781 was in part drawn from plants of two years' growth. A study of his Garden Book under date of March 17, 1794, reveals this entry: "Planted 200 paccan nuts and seeds of Kentucky coffee." (P. 20.) He also records a much larger planting May 26, 1802. "Also planted a great number of Paccan nuts, in the same rows of those planted the last two years." (P. 30.) This reference to plantings of "the last two years" seems to refer to unrecorded plantings, including the nuts from Clark, of New Orleans, which might have given him the young trees referred to in his description. He mentions another planting of "25 paccans" on March 17 and 18, 1812.

One of the most interesting of the old trees of Germantown, until relatively recent years, was a pecan grown from a nut brought back from the Arkansas country in 1819 or 1820 by Thomas Nuttall. The botanist presented the nut to his friend, Reuben Haines, a man prominent in scientific and agricultural circles in Philadelphia, who in turn gave it to his neighbor, Daniel Pastorius, who planted it. The tree reached a large size and bore fruit.[3] This history is taken from a very interesting account of the rare plants of Germantown which presents much historical information in addition to that indicated by its title.

A careful search on the old estates of the eastern coast would in all probability lead to the discovery of still other early plantings which might prove highly interesting.[4]

IMPROVEMENT OF THE PECAN.

There is perhaps little to be said on this part of the subject but even in early days some indications are seen of coming efforts to improve the nut. The recognition of locally well-known nuts of a superior type is directly asserted in Clark's letter of 1799 to Jefferson. The perpetuation of this superiority through grafting or budding would have been a valuable advance. On August 2, 1760, Jefferson records in his Garden Book that he "inoculated English walnut buds into stocks of the Black walnut" at his old home, Shadwell: had his duties left him at Monticello we should perhaps have found him budding pecans at a later date. So far as I have learned, however, this experiment was left for later hands.

[2] Diary of George Washington. Vol. 22: 1465.

[3] Jellett, Edwin C., Germantown Old and New. Its Rare and Notable Plants. 1904: 71.

[4] Littlepage, Thomas P., Jefferson and Washington—Pecan Planters. American Nut Journal, 6: 6, 1917.

Whether or not to Abner Landrum belongs the credit of first budding pecans, I am not able to say. However, on February 28, 1822, he reports from Edgefield, South Carolina, the results of experiments made in budding several difficult species and says:

> The pecan (*Carya oliveaeformis*) did not appear to take so well as the walnut but my trials were made rather late in the season.[1]

In experiments carried out during the year 1822 he had better success. He reports late in that year:

> I have, this summer, budded some dozens of the pecan on the common hickory nut, without a single failure as yet; and some of them are growing finely.[2]

The notes here collected are to be regarded only as a fragmentary contribution to the history of this interesting subject.

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[1] American Farmer. 4 : 7, 1822.
[2] Ibid. 4 : 269, 1822.

FLORAL ASPECTS OF THE HAWAIIAN ISLANDS.

By A. S. Hitchcock.

[With 25 plates.]

The flora of the Hawaiian (Sandwich) Islands is of unusual interest because the group is the most isolated upon the globe. Disregarding mere reefs or islets, the distances to land in the various directions are: Unalaska, 2,016 miles; San Francisco, 2,100 miles; Samoa, 2,263 miles; Yokohama, 3,445 miles. Because of this isolation the native flora is peculiar and the endemic element is proportionately large.

During the summer of 1916 the writer visited the Hawaiian Islands for the purpose of studying their flora. In these investigations he was assisted by his son, A. E. Hitchcock. Collections were made on the six larger islands of the group; that is, on all except Niihau and Kahoolawe. Brief accounts of this trip have been given elsewhere.[1] In the present article an attempt will be made to give a general view of the more prominent features of the flora and to record the impressions that appeal to a botanical traveler.

The climate is strictly tropical but, because of the proximity of the ocean and because of the moderating influence of the trade wind, the temperatures are not unpleasantly high. The summer daily maximum is about 85° F. at Honolulu. At higher altitudes the climate is cooler and on the summits of the high mountains of the island of Hawaii there is much snow, some of which persists throughout the year. The rainfall varies greatly in different parts of the same island. All the islands are mountainous and the mountains intercept the trade winds, causing a heavy rainfall upon the windward side of the islands. The lee side is dry or even arid in places. In the vicinity of Honolulu, which lies on the westerly side of the island of Oahu, the rainfall at the water front may be as low as 15 inches, but increases rapidly toward the mountains to the east, at the crest of which, about 6 miles away, the rainfall may be as high as 300 inches. In general the rainy season is from November to March, but in the vicinity of the mountains the rains extend

[1] Explorations and Field-work of the Smithsonian Institution in 1916 (Smiths. Misc. Coll. Vol. 66, no. 17, p. 58, 1917). A botanical trip to the Hawaiian Islands (Sci. Monthly, vol. 5, p. 323, and p. 419, 1917).

throughout the year, though the amount may be greater during the winter. One of the rainiest spots is the summit of Waialeale, the highest peak of Kauai (5,170 feet), where the rainfall is as much as 600 inches. Professor Campbell records the rainfall here as follows:[1]

1912, 383.35 inches.
1913, 462.00 inches.
1914, 610.00 inches.
1915, 490.00 inches.
1916, 529.70 inches.

The chief agricultural industries of the islands are, the production of sugar, the raising of stock, and the growing of pineapples. Sugar cane is grown on the lowlands of Oahu, Kauai, Maui, and Hawaii, where sufficient water is available either from the rainfall or from irrigation. The ranches for stock raising are on the plains and treeless slopes on the leeward sides of the islands, especially on western and northern Hawaii, western Molokai, nearly all of Lanai, and the western part of East Maui. Pineapples are grown chiefly on Oahu in localities not well suited to sugar.

In earlier days horses, cattle, hogs, and goats were introduced and allowed to run wild. They increased rapidly and became a menace to the vegetation. Large areas were almost denuded of native plants and their place has been taken by introduced weeds, especially such shrubs as guava and lantana. In recent years these wild animals have been hunted and killed to such an extent that they are now nearly exterminated, a few flocks of goats being found in the more inaccessible canyons, and small herds of pigs in the upper forests. Much harm to the native vegetation has been done and many species have been greatly restricted in their range, some species being actually exterminated.

Land that has been denuded by stock is subjected to the danger of further denudation by wind in the drier regions. Wind erosion is especially noticeable on the northern end of Lanai and the northwestern part of Molokai. Kahoolawe, a small island not visited by us, is said to have suffered severely from the denuding effects of the strong trade wind. This island lies in the path of the trade wind that blows between the mountain masses on East and West Maui, while the low-lying part of Lanai to the north receives the full force of the wind as it blows between Molokai and West Maui.

The islands are of volcanic origin and the rocks are practically all volcanic. The island mass rises from the ocean floor about 18,000 feet below the surface. The great cones of the high mountains of Hawaii (Mauna Kea, 13,825 feet; Mauna Loa, 13,675 feet) give the unusual difference of level between the summit and base of about

[1] Douglas H. Campbell. An extraordinary rainfall record. Science, n. ser. 40: 511. 1917.

32,000 feet. Geologically Kauai is the oldest island and Hawaii the youngest. On Kauai are found deep and rugged canyons the result of age-long erosion. On Hawaii vast stretches of lava are as fresh as if the material had barely had time to cool; and several flows have broken forth within the last century. There are innumerable small craters dotted over the main mountain mass. There is a great variety in the kinds of lava. Some of the cones are made up of cinders, a soft material that yields to the foot like sand. Others are made up of hard lava, of which two main divisions are recognized, aa and pahoehoe, Hawaiian terms meaning rough and smooth. The former is exceedingly rough and broken and presents great difficulties to the traveler who attempts to walk over its surface. In the course of time the lava disintegrates sufficiently to allow vegetation to obtain a foothold. The advent of plants is hastened by moisture, the lava becoming covered with vegetation much sooner in the regions of heavy rainfall than upon the arid slopes.

It will be impossible to give an ecological survey of the islands but it may be of interest to present a brief account of the flora and its relation to environment as it impresses a visiting botanist.

The most striking botanical feature that greets the traveler on his arrival at Honolulu is the display of ornamental plants, including flowering trees, shrubs, vines, and plants grown for the beauty of their foliage or the stateliness of their habit, practically all of which are of foreign origin.

There is a great variety of palms, including such pinnate-leaved species as the date, the coconut, and greatest favorite of all, the royal, and many fan palms and a few fishtail palms. The stately royal palm with its smooth columnar trunk is a familiar tree in parks and private grounds.

Among the street trees there are the pink shower (*Cassia nodosa*) with large racemes of beautiful pink and white flowers, the golden shower (*Cassia fistula*) with yellow flowers and woody, smooth, straight, cylindric pods 15 inches long, both with large compound leaves, and the flame tree (*Delonix regia*) with great masses of scarlet flowers on the otherwise naked branches, the leaves being deciduous. The monkey-pod or rain tree (*Samanea saman*), a large, round-topped or umbrella-shaped tree with an immense spread of branches, is common in parks.

Among the shrubs the most common is the hibiscus, of which there are scores of varieties, involving several species (especially *Hibiscus rosa-sinensis*). These are commonly used for hedges and produce a continuing crop of large, bell-shaped flowers, varying through shades of white, pink, and scarlet. Clambering over a wall around the grounds of Punahou College is a fine growth of night-blooming

cereus. This blooms en masse at intervals of several months and produces a remarkable display. The flowers open in the evening and close the following morning, so they must be observed by the light of lanterns. The writer was so fortunate as to obtain photographs of this hedge early in the morning.

Two shrubs are very commonly used for hedges, but it is the foliage instead of the flowers that is attractive. One is the acalypha (*Acalypha wilkesiana*), a plant of the family Euphorbiaceae, with simple leaves of various shades of brown, pink, and yellow. The other is a species of the family Araliaceae (*Nothopanax guilfoylei*), with pinnate leaves, consisting of five to seven white-margined leaflets. The croton (*Codiaeum variegatum*), an ally of the acalypha, is sometimes used for hedges, but more often is grown in clumps as a lawn ornamental. The narrow leaves are variously spotted and mottled and often spirally twisted.

Among the numerous ornamental, woody vines is the bougainvillea (*B. spectabilis*), which produces a great profusion of red or purple flowers. What appear to be flowers are, however, showy petal-like bracts.

In addition to those mentioned there are several that are familiar as cultivated trees in California and southern Florida, such as the pepper tree, mango, ironwood (*Casuarina equisetifolia*), banyan, and yellow poinciana (*Peltophorum inerme*).

An important and common exotic tree, but now thoroughly naturalized, is the algaroba or kiawe (*Prosopis juliflora*). Contrary to the usual experience where foreign trees or shrubs have been introduced and then run wild, this tree has proved to be a great blessing to the Hawaiian Islands. The original tree is still alive on Fort Street, Honolulu, where it was planted in 1828 by Father Bachelot, founder of the Catholic Mission. The algaroba now occupies extensive areas in the lowlands on all the islands, especially in the arid belts near the coast on the lee side, where it forms forests to the exclusion of all other plants. Fortunately it is very useful in two ways. The flowers are the source of honey of which commodity hundreds of tons are produced annually. The pods furnish a nutritious feed for stock. The foliage is not eaten but the pods as they fall from the trees are eagerly sought by all kinds of domestic animals, and in the dry season are an important or sometimes the only source of forage upon the ranches. Their value as fodder has led to the invention of machinery to pulverize the pods so that they may be more completely and economically used. The algaroba is freely planted as an ornamental tree because of its graceful aspect and feathery, drooping branches.

Contrasted with the satisfactory results following the introduction of the algaroba we have the conspicuously disastrous effect of in-

troducing the lantana and guava. The lantana (*L. camara*) is cultivated for ornament because of the flat-topped clusters of pink or lavender parti-colored flowers. It has run wild and now occupies hundreds of acres on the drier parts of the slopes below the rain forest. It is of no value and occupies the soil to the exclusion of pasture plants. The guava, cultivated for its fruit, about the size and appearance of a lemon, from which the delicious guava jelly is made, has also run wild and occupies large areas of pasture land, or what would be pasture if these two pestiferous shrubs could be exterminated.

Another introduced shrub or tree is the prickly-pear cactus (*Opuntia megacantha*). This plant is now common on the dry parts of all the islands, sometimes forming forests. However, it is not entirely a pest, for in times of stress it furnishes no inconsiderable proportion of the forage on the ranches, because the cattle have learned to eat the juicy joints in spite of the numerous needlelike spines.

The native flora has been almost entirely replaced by introduced weeds in all the lowlands, especially in the vicinity of the towns.

All the islands are mountainous. Kauai, a nearly circular island, is mountainous through the interior, the highest point being Waialeale, in the center (5,170 feet). Oahu has two ranges of mountains—the Koolau Range on the east and the Waianae Range on the west, the highest point being Mount Kaala, in the latter range (4,030 feet). Molokai, an oblong island, has a range in the eastern half along the north side, the highest point of which is Kamakua Peak (4,958 feet). Maui consists of two mountain masses—East and West Maui—with a low isthmus between. The highest peak of West Maui is Puu Kukui (5,788 feet). East Maui is centered around the immense crater Haleakala, said to be the largest crater in the world. The highest part of the rim, a point on the western side, has an altitude of 10,032 feet. Lanai, a small island west of Maui, is mountainous on the eastern side, rising there to about 3,500 feet. Hawaii, the largest island of the group, is truly majestic in the height of its mountains. There are four mountain groups. The mass of the island is made up mainly of the two great cones, Mauna Kea (13,825 feet) and Mauna Loa (13,675 feet). There are two lesser mountain groups—the Hualalai Mountains (8,269 feet), near the west coast, and the Kohala Mountains (5,480 feet), in the projection at the northwest corner. These mountains have a high rainfall where they intercept the trade wind, the region of greatest precipitation being at the summit and somewhat to the leeward (except the high peaks as noted below). The Hualalai Mountains are comparatively dry because they are in the lee of Mauna Kea. In many places the slope is gradual from sea to summit. In fact, all the mountains are, in general,

rather flat cones, the precipitous cliffs and valleys being due to erosion, though there are high cliffs (palis) on the north and east sides of some of the mountains, as the Kohalas and the mountains of Molokai, and the walls of the great craters. As one looks from the sea on the northeast coast of Hawaii to the summit of Mauna Kea, a distance of perhaps 20 miles, the slope is so even that it is difficult to convince one's self that he is looking up to a peak nearly 14,000 feet above him. The famous volcano Kilauea lies on the southeast slope of Mauna Loa at an altitude of about 4,000 feet. In one part of the large crater, about 3 miles across and 500 feet deep, is the lava pit called Halemaumau, a circular depression about 1,500 feet wide at the top and several hundred feet deep. The view from the rim of this pit is extremely fascinating, especially at night. The liquid lava seems to boil from the force of the escaping gases and the waves produce a loud roar as they splash against the margins.

The distribution of the flora upon the islands depends upon rainfall, altitude, and soil. The rainfall is highest in the mountains and decreases toward the leeward side of the islands. The annual precipitation in the rain belt is usually from 100 to 300 inches, but in some localities exceeds this large amount. On the southwestern sides of the islands the rainfall becomes so slight that the climate is arid. The rain zone extends up on the mountains to only 5,000 to 6,000 feet. Consequently, on the high peaks of Hawaii and East Maui the rainfall decreases toward the summits. The character of the flora changes with the rainfall. Hence, rain forests occupy the regions of high rainfall, while the slopes of western Molokai, East Maui, and Lanai and the plains of central Oahu and Hawaii are covered with grasses and other herbaceous vegetation, with sometimes intermingled areas of open, scrubby forest. The peaks of Mauna Kea and Mauna Loa are nearly devoid of vegetation above 10,000 feet.

The grasses of the Hawaiian Islands number about 100 species, including the large number of introduced weeds. The native species are less than half the total. As grasses are inhabitants of open ground they are rare in the rain forests. A well-known, useful native grass is the pili (*Heteropogon contortus*) which is a valuable range grass. This species was used by the early Hawaiian inhabitants to thatch their cabins, the grasses being fastened to a light frame work to form the walls and roof. An introduced species, Hilo grass (*Paspalum conjugatum*), has become a pest, having become established almost to the exclusion of other plants over wide areas on the wet slopes below the rain forest. It is said to have been introduced at Hilo from tropical America about 1840. It is of little value for pasture as stock will not eat it except when forced to from hunger. Another common and equally useless species, *Paspalum orbiculare*, which seems to have received no common name, occurs widely dis-

tributed in about the kind of soil that is suited to Hilo grass. Pilipiliula (*Chrysopogon aciculatus*) is the name given to a pestiferous little grass covering much of the dry plain in the interior of Oahu. This grass, introduced from the East Indies, produces sharp-pointed seeds which penetrate the clothing of those who walk through it and produce much discomfort. Bermuda grass is thoroughly naturalized in the drier localities and is extensively used as a lawn and park grass. Its native name is manienie, a name which was applied by the Hawaiians originally to *Stenotaphrum secundatum*, another creeping grass. The latter species is frequent in tropical regions and is known in the southern United States as St. Augustine grass.

The genus Eragrostis is represented by several native species, most of which are endemic. One species (*E. variabilis*) is characteristic of the wind-swept open slopes of the Nuuanu Pali, a pass in the Koolau Range east of Honolulu. Upon the plain between Mauna Kea and Mauna Loa, a great stock-range country, a tall slender tufted species (*E. atropioides*) is the prevailing grass.

The genus Panicum is represented also by several native species. *Panicum torridum* and its allies, fuzzy annuals called by the general name kakonakona, are winter grasses that follow the rains on the semiarid plains, and furnish a considerable portion of the forage at that time. Three species of Panicum (*P. imbricatum*, *P. isachnoides*, and *P. monticola*) are characteristic of the open bogs of the wet mountain summits, where they form hemispherical tussocks, consisting of a mass of old roots and stems with a covering of living shoots an inch or two long.

Upon the upper slopes of Mauna Kea and other high mountains toward the limit of tree growth there are three characteristic species of grass that are found sometimes in great abundance. They are all tufted species that furnish forage to the stock that range through these regions. One of these (*Agrostis sandwicensis*) is endemic, the other two (*Deschampsia australis* and *Trisetum glomeratum*) are found in the South Sea Islands.

Several European species of forage grasses have been introduced upon the ranches and have become established at medium altitudes (3,000 to 7,000 feet). Of these may be mentioned timothy, orchard grass, meadow fescue, velvet grass, redtop, Italian rye grass, rescue grass, and bluegrass. *Paspalum dilatatum*, a native of South America, is giving much promise as a pasture grass in these regions. At lower altitudes Natal grass or Natal redtop (*Tricholaena rosea*) is being used as a meadow grass, and Rhodes grass (*Chloris gayana*) is coming into use for the same purpose. Sudan grass is being tried and seems well adapted to the drier areas.

In the central part of Kauai there is a species of Poa (*P. siphonoglossa*) which is remarkable in its aspect, especially for this genus

which includes the bluegrasses. The stems grow in large tufts along steep banks. The young stems and flowering shoots are not particularly unusual but the old stems elongate to as much as 10 or 15 feet, lose their blades, and hang down the bank in long green rushlike masses that are very striking in appearance.

The forest trees comprise a great many species. It is astonishing how many of these species, and in fact species of plants in general, have been given Hawaiian names by the early inhabitants. Only a few are of sufficient importance to be mentioned here. The commonest tree on the islands is the ohia or ohia lehua (*Metrosideros polymorpha*) a member of the myrtle family, having a very wide altitudinal range and growing under a great variety of conditions. In size it varies from a mere shrub at high altitudes, to a giant forest tree in the middle forest zone. The tree has white furrowed bark like that of our white oak and beautiful scarlet flowers with numerous protruding stamens. The wood is hard and durable, and is used for many purposes, including paving blocks and railroad ties.

Another forest tree is the koa (*Acacia koa*), important because of its abundance and because of its economic value. Next to the ohia it is the most numerous among the larger trees, and is widely distributed throughout the islands. When growing in the open the koa forms a comparatively low widely spreading tree with a thick short trunk. But when growing in the rain forest among other trees it forms tall shapely trunks 40 or 50 feet to the branches. The wood is used in cabinetwork and is becoming familiar to Americans through its use for ukuleles, the mandolinlike musical instruments now so popular. The foliage is interesting because of its polymorphism. On the young trees or on vigorous shoots of old trees the leaves are twice pinnate, much like those of our honey locust, but have laterally compressed or flattened petioles. The normal mature foliage, however, consists of these flattened petioles or phyllodes, the remainder of the leaf not developing.

Another species of koa (*Acacia koaia*) is found in the drier regions of the southern islands.

The traveler is certain to inquire concerning a common tree that attracts attention because of its peculiar light or olive green foliage that is in marked contrast to the prevailing green of the forests. This is the kukui (*Aleurites moluccana*), found widely distributed in the islands at lower altitudes up to about 2,000 feet. The leaves remind one of those of the castor oil plant, which the young kukui plants closely resemble. The nuts of the kukui are rich in oil, which is an important article of commerce. The species has a wide range in Polynesia and tropical Asia. In the English colonies it is called candleberry or candlenut tree.

In the regions where they grow, two monocotyledenous trees of peculiar habit, the halapepe and puhala, attract attention. The halapepe (*Dracaena aurea*) belongs to the lily family and is allied to our yuccas. The narrow lilylike leaves are clustered at the ends of the branches, where are produced also the flowers and fruit, the latter a cluster of bright red berries about the size of marbles. The halapepe is a xerophyte, being found in the dry districts especially on aa lava. The leaves are relished by cattle. The puhala (*Pandanus odoratissimus*) belongs to the genus of screw pines. It is a scraggly tree with long narrow coriaceous prickly-margined leaves clustered at the ends of the branches in the spiral or corkscrew arrangement, numerous stilt roots at the base, and aerial roots from the branches. The large red or orange-colored compound fuit resembles a pineapple. There is a fine forest of these trees near Hilo. Belonging to the same family is a tall woody climber (*Freycinetia arnotti*) which is common in the lower woods.

If one ventures on to the upper slopes of the mountains of Hawaii he is sure to come in contact with the mamani (*Sophora chrysophylla*) a member of the family Leguminosae. It grows on several of the islands but is particularly noticeable toward the upper limit of tree growth on the mountains, where it forms small round-topped trees, with silvery-brown pinnate leaves like those of our black locust, drooping racemes of golden-yellow, pea-shaped flowers, and long pods constricted between the seeds.

The wiliwili tree will attract attention in the autumn at the lower levels on the dry side of the islands. At this season it is devoid of leaves and is conspicuous among evergreen vegetation. The seeds are a bright scarlet and are used for ornament. The wood is said to be the lightest of any kind growing on the islands, and is used for outriggers upon canoes.

The mountain apple (*Jambosa malaccensis*) is of interest because of its edible fruits. These are spheroidal, 2 or 3 inches in diameter, white or red, thin-skinned, very watery, but pleasant-flavored, and contain usually one large seed. The mountain apple is found in lowland valleys.

There are several species of trees of the mallow family that are worthy of remark because they are on the verge of extinction and illustrate the harm done to vegetation by the grazing industry. One is the kokio or native red cotton (*Kokia rockii*) described recently by Lewton.[1] This is a small tree with magnificent hibiscus-shaped red flowers about 4 inches long. It is endemic on the island of Hawaii and is confined to the dry region on the western side of the island, where it is scattered here and there on the rough lava of

[1] Smiths. Misc. Coll. 60: 5. 1912.

North Kona. The species comprises a comparatively few individuals and these are decreasing in number because of the incursions of cattle. Mr. Robert Hind, upon whose ranch at Puu Waawaa the trees are growing, is giving them protection and thus preserving the species from extinction.

Another species, a close ally of the preceding, is called *Kokia drynarioides.* A few years ago the species was reduced to a single plant growing in the dry western part of Molokai. Recently this individual succumbed to the inevitable. Fortunately seeds from this tree had been planted and it is hoped that the species may be perpetuated in cultivation. The writer inspected one of the seedlings in the grounds of Mr. George P. Cooke of Molokai.

Another genus of this family contains three species, remarkable for the paucity of individuals. All are nearing extinction. Professor Rock states[1] that of *Hibiscadelphus giffordianus* there is but a single tree near the Kilauea volcano, and of *H. wilderianus* there is a single one on the southern slope of Haleakala. Of *H. hualalaiensis* there are about a dozen trees. All are succumbing to the ravages of cattle.

Aside from the shrubs already mentioned as being pestiferous weeds, the guava and the lantana, there are two others that were introduced at an early date and are now thoroughly naturalized but are not so troublesome as the two just mentioned. These are the klu (*Acacia farnesiana*) and the false koa (*Leucaena glauca*). They are found in waste land especially on the dry side of the islands. The klu is a prickly scraggly shrub with heads of yellow flowers. The false koa is without spines, has heads of white flowers and very flat pods. This species is giving promise as a forage plant. By proper treatment the woody stem may be kept trimmed close to the ground, a succession of young shoots that are suitable for forage being sent up.

The sensitive plant (*Mimosa pudica*) a well-known and interesting undershrub common in tropical America, has become established in open dry pastures. The twice pinnate leaves are very sensitive to the touch, so sensitive that they respond to the slight jar of the earth in walking, and will close in the vicinity if one steps heavily among the plants.

The isolation of the islands has led to the unusual development of certain families or genera of plants. One of these families that attracts the attention of the visitor, is the family Lobeliaceae. There are over 100 species belonging to 6 genera, making it one of the largest families of plants on the islands, the number of species being twice that in the whole of the United States north of Mexico. The family is interesting not only from the number of species, but from the

[1] The indigenous trees of the Hawaiian Islands, 297. 1913.

striking habit of most of these. The prevailing form is palmlike, a slender trunk crowned with a cluster of narrow leaves. In some of the larger species the trunk may be as much as 40 feet high. The flowers are clustered at the base of the leaves or are borne in showy racemes, and in many species are remarkably beautiful.

To the botanist and layman alike, there is no group of plants that presents more of interest than the ferns. They are everywhere from desert to rain forest and from sea level to the upper limit of vegetation on the high mountains. In size they vary from the gigantic tree fern to the minute epiphytic ferns less than an inch long. In some regions they are so numerous in both species and individuals that they impart the dominating aspect to the scene, and other plants appear as individuals scattered among them. The ferns and their allies number about 185 species. As individuals the tree ferns are the most conspicuous. They comprise 3 species belonging to the genus Cibotium. A common and widely distributed species is *C. menziesii* in which the twice pinnate fronds are as much as 12 feet long and 5 feet broad, raised upon trunks usually only a few feet tall but sometimes as much as 30 feet (Rock). At the base of the leafstalk there is a growth of soft yellowish wool called pulu by the Hawaiians and used by them for stuffing pillows and mattresses.

Contrasted with these giants are the pygmies in the form of numerous species of epiphytes. In the rain forest the epiphytes, including ferns, mosses, and lichens, cover every available trunk and branch with a soggy coating dripping with moisture. Some of the ferns creep over the surface by means of rootstocks; others are tufted. In some of these epiphytic forms the fronds are narrow and only an inch long with one or two fruit spots upon them.

A common and, to the explorer, troublesome fern is a climbing species (*Gleichenia dichotoma*) with repeatedly forked stems. These trail over bushes and often form impenetrable thickets over large areas.

On lava flows on the upper slopes of the high mountains, extending to the upper limit of vegetation, is a tufted coriaceous species (*Polypodium pellucidum*) about a foot high, with pinnatifid fronds. In dry areas the lobes incurve until the tips touch over the upper surface. Plants of this species may be found in holes in the lava as the last outposts of vegetation on Mauna Loa.

To the layman a description of the flora of the Hawaiian Islands would be incomplete without a reference to the silver sword (*Argyroxiphium sandwicense*). This rare and striking plant is found on the cinder slopes in the crater of Haleakala and on upper slopes of the high mountains of Hawaii. The form in the crater of Haleakala is slightly different from that on Hawaii and has been distinguished

as a variety (var. *macrocephalum*). The plants produce a tuft of numerous narrow stiff sharp-pointed leaves about a foot long, entirely covered with a silvery white closely appressed wool. The tufts appear to increase in size for several years from little balls up to tussocks 2 feet in diameter. Finally a flower stalk shoots up from the center bearing numerous heads of flowers about an inch in diameter with yellow center and purple rays. On the cinder cones in Haleakala the plants grow scattered here and there far above other vegetation in the most desolate and arid spots. At a distance these groups of plants, shiny white against the bleak brown slopes, have the appearance of a flock of sheep. On Mauna Kea the silver sword was seen on the north slope above the Kukaiau ranch. No living plants were observed on Mauna Loa, but many dead stems indicated its presence.

A second species of the genus grows in the crater of Haleakala, but is confined to cliffs and inaccessible rocks where the plants have escaped the ravages of goats. This species (*A. virescens*) has been called the green silver sword because the leaves are green instead of shiny white.

Another remarkable plant is the apé apé (*Gunnera petaloidea*). In appearance it reminds one of a giant pieplant or rhubarb, the leaves being circular and as much as 4 feet in diameter. This species grows in the rainy zones mostly on the sides of precipitous valleys. The leaves are very conspicuous because of their size in a region where broad leaves are unusual.

At the lower edge of the forest zone there is a common shrubby liliaceous plant, with cannalike leaves 1 to 2 feet long and 3 or 4 inches wide, known as ti or ki (*Cordyline terminalis*). The leaves are much used for wrapping fish in the markets. The natives had many uses for the leaves, roots, and stalks.

The rain forests include a large number of different kinds of trees and shrubs, mostly with inconspicuous flowers and indistinctive foliage. The trunks are frequently smooth and light colored and the leaves usually small. In much of the area where the rainfall is high the forest, though dense and impenetrable, is scrubby, the trees being small and gnarly, often not over 20 to 30 feet tall. This condition seems to be due to the character of the soil, which is not sufficiently fertile to support a growth of large trees. Under more favorable conditions, in some of the richer valleys, the forest may reach a higher development, including trees 100 feet tall.

From the ecological standpoint the open bogs present an interesting phase of the Hawaiian vegetation. These are found on the summits of the mountains that reach an altitude of about 5,000 feet and consequently receive a maximum rainfall. They occur to a limited

extent on Molokai, are well developed on West Maui, and reach a maximum on the central mountains of Kauai. They are found at or near the summit of ridges where the land is level or slightly sloping. The vegetation consists of herbs and low shrubs; tall shrubs and trees are lacking, except as intrusions from the surrounding flora. Many of the plants grow in tussocks so that the surface is a succession of irregular clumps and mounds. A characteristic and often dominant plant of these bogs is a kind of sedge (*Oreobolus furcatus*) which forms beautiful dark-green hemispherical tussocks as much as a foot in diameter, the stiff short leaves closely packed forming an even surface. Three species of tussock-forming panicums are found in these bogs (see a preceding paragraph on grasses). Two beautiful species of Lobelia (*L. gaudichaudii* on West Maui; *L. kauaiensis* on Kauai) are found here. The plant is 4 to 10 feet tall with a large panicle of cream-colored or pinkish flowers 3 or 4 inches long, as many as 100 in a single inflorescence. Resembling the lobelia as to shape of the plant is a composite (*Wilkesia grayana*) with sword-shaped leaves and long racemes of globose flower heads.

Among the smaller plants is a little sundew, apparently the same as the American species (*Drosera longifolia*), and two species of beautiful little blue violets (*Viola kauaiensis* and *V. mauiensis*). Growing in the scrubby rain forest more or less epiphytic, is a shrubby violet (*Viola robusta*), the flowers resembling those of our little Johnny-jump-up, but the plant, a shrub 3 to 5 feet tall.

When the flora of the Hawaiian Islands is compared with that of other tropical lands, more especially when compared with the flora or tropical America, certain families that give a dominating impress to the latter regions are found to be poorly represented in the former. The orchid family, so characteristic of tropical lands throughout the world, is in the Hawaiian Islands conspicuous by its absence. The family is not absolutely without representation, but there are only three species, belonging to as many genera, and all are rare, inconspicuous terrestrial forms, strangely in contrast with the showy epiphytic orchids of other tropical regions.

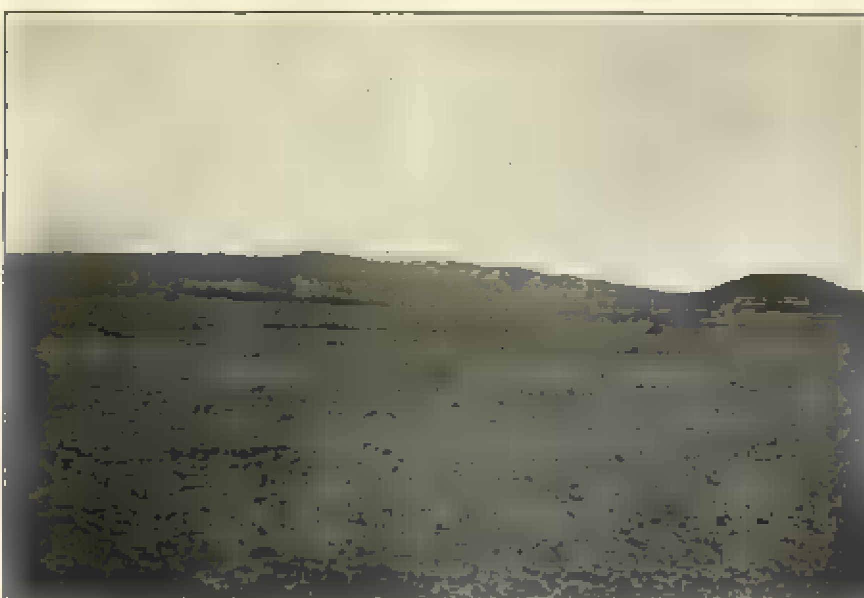
The characteristic palm family is represented in the native flora only by about 10 species of Pritchardia, a genus of fan palms, most of the species having been published since the appearance of Hillebrand's Flora of the Hawaiian Islands. All the species are rare, being represented by scattered specimens in remote localities.

The tropical family Melastomataceæ, with its triple-nerved leaves, is entirely unrepresented and the great family Compositæ, the largest of our plant families, is represented by surprisingly few native species. The mint family (Labiatae) like the preceding has a disproportionately small number of species, these belonging mostly to

the two endemic genera Phyllostegia and Stenogyne. Entirely absent from the islands are the mangroves, those swamp trees so characteristic of most tropical shores.

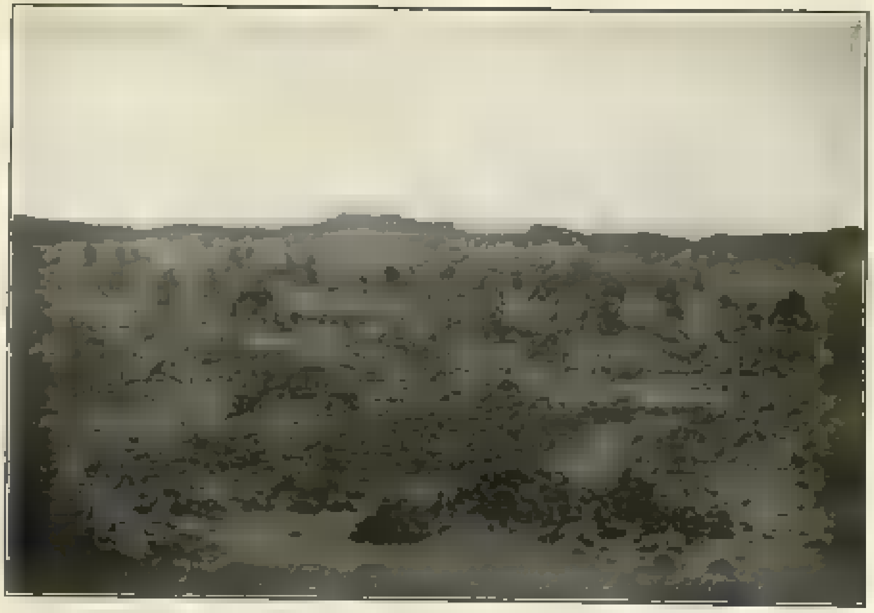
Taking everything into consideration, the American botanist will be amply repaid for all the time and effort expended in visiting the Hawaiian Islands. He will be brought in contact not only with a new plant world, but with many curious and remarkable natural phenomena. He will be able to prosecute his researches under unusually pleasant and favorable conditions, a salubrious climate, helpful and sympathetic inhabitants, and an absence of those banes of the botanical collector, pestiferous insects and poisonous reptiles.

1. SNOW BANKS NEAR THE SUMMIT OF MAUNA KEA. THE CONE IN THE DISTANCE IS NOT THE SUMMIT, WHICH WAS IN THE REAR OF THE CAMERA.



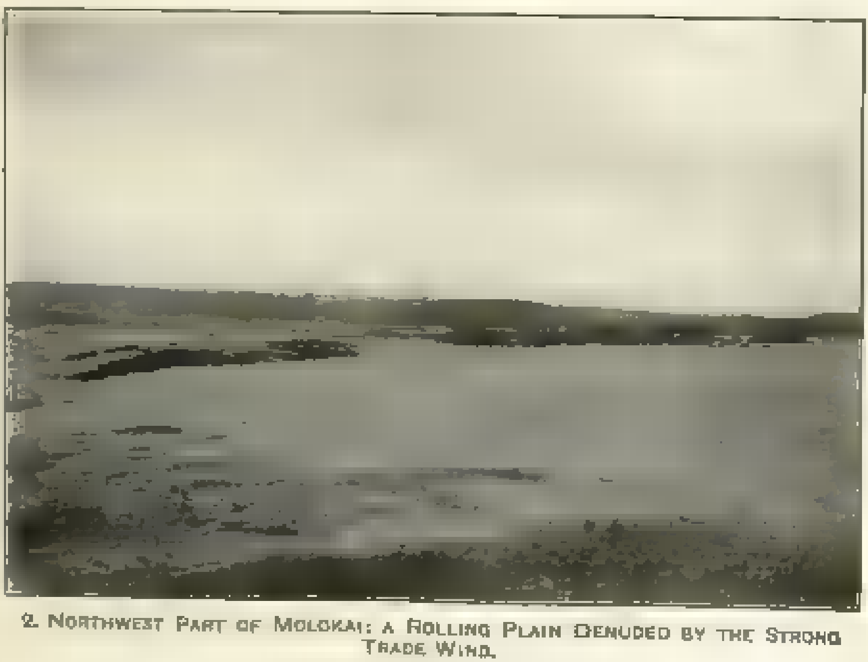
2. GRAZING LAND ON MOLOKAI RANCH, CENTRAL MOLOKAI, LOOKING EAST TOWARD THE MOUNTAINS.

The western half of the island is a level or rolling plain.



1. NORTHEASTERN PART OF LANAI, SHOWING THE EFFECT OF WIND EROSION.

The columns are hard lava, from which the surrounding material has been blown away.

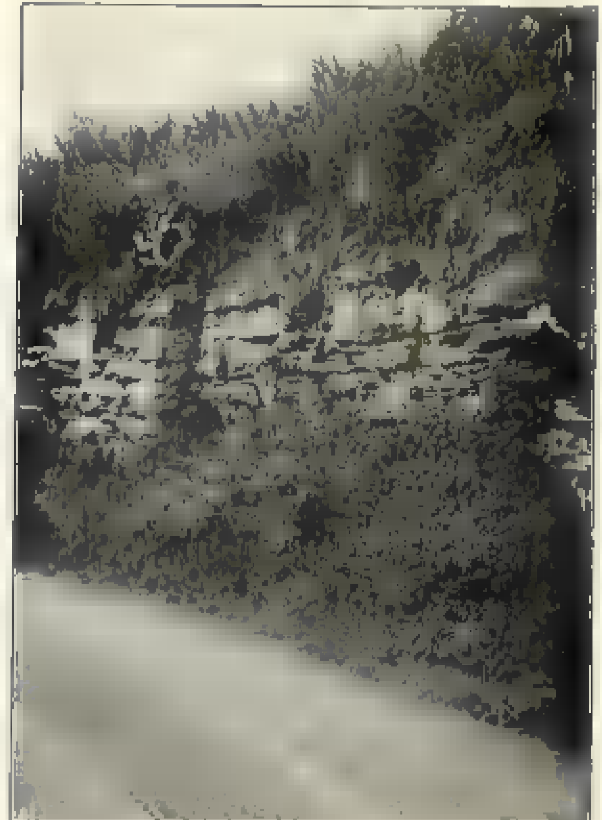


2. NORTHWEST PART OF MOLOKAI: A ROLLING PLAIN DENUDED BY THE STRONG TRADE WIND.

The hillocks are held by Bermuda grass.

1. OLOKELE GULCH, KAUAI. A DEEPLY ERODED CANYON CHARACTERISTIC OF THIS ISLAND.

The trees with light-colored foliage on the lower slopes are kukui (*Aleurites moluccana*). The plant in the foreground and on the sky line at the left is the ki (*Cordyline terminalis*).



2. STRATIFIED LAVA ON THE ROAD TO SCHOFIELD BARRACKS, OAHU.

Sugar cane in the field above.

1. THE SUMMIT OF MAUNA KEA, A CINDER CONE ENTIRELY DEVOID OF VEGETATION; ALTITUDE 13,825 FEET.

2. NEAR THE SUMMIT OF MAUNA KEA.

At the left is an ancient quarry to which the early Hawaiians came for material for stone axes. The lava is very hard and will take a sharp edge.

1. VIEW ON MAUNA LOA AT ABOUT 10,000 FEET ALTITUDE. SEVERAL SMALL CRATERS IN THE DISTANCE.

2. CRATER AT THE SUMMIT OF MAUNA LOA. VIEW FROM THE EAST RIM.

1. PUU WAAWAA, A HILL OR OLD CRATER NEAR THE HUALALAI MOUNTAINS.

In the foreground is the aa (rough) lava of an old flow. In the middle distance is a meadow of Rhodes grass (*Chloris gayana*).

2. SCRUBBY FOREST ON AA LAVA, PUU WAAWAA RANCH.

Note the exceedingly rough surface of the lava.

1. VIEW IN THE HILLEBRAND GARDEN.

This garden now owned by Mrs. Foster, formerly belonged to Dr. Hillebrand, the author of the Flora of the Hawaiian Islands.

2. AN AROID (MONSTERA DELICIOSA) CLIMBING ON A COCONUT IN MOANALUA PARK, HONOLULU.

1. A Group of Papyrus Reeds in Moanalua Park.

2. Diamond Head, from Kapiolani Park, Honolulu.

This crater is a prominent landmark from the ocean.

1. THE FLAME TREE (DELONIX REGIA), IN FULL FLOWER.

The flowers are bright scarlet and appear when most of the leaves are gone.

2. COCONUT TREES ALONG THE SHORE NEAR NAPOOPOO, WESTERN HAWAII.

1. A HEDGE OF NIGHT-BLOOMING CEREUS ON A WALL AT PUNAHOU COLLEGE, HONOLULU.

Taken before sunrise.

2. A FEW FLOWERS OF THE NIGHT-BLOOMING CEREUS.

1. THE YELLOW POINCIANA (PELTOPHORUM INERME), A RATHER COMMON STREET TREE IN HONOLULU.

2. A MANGO TREE.

The mango is a delicious tropical fruit, common in the islands.

1. VIEW IN MOANALUA PARK.

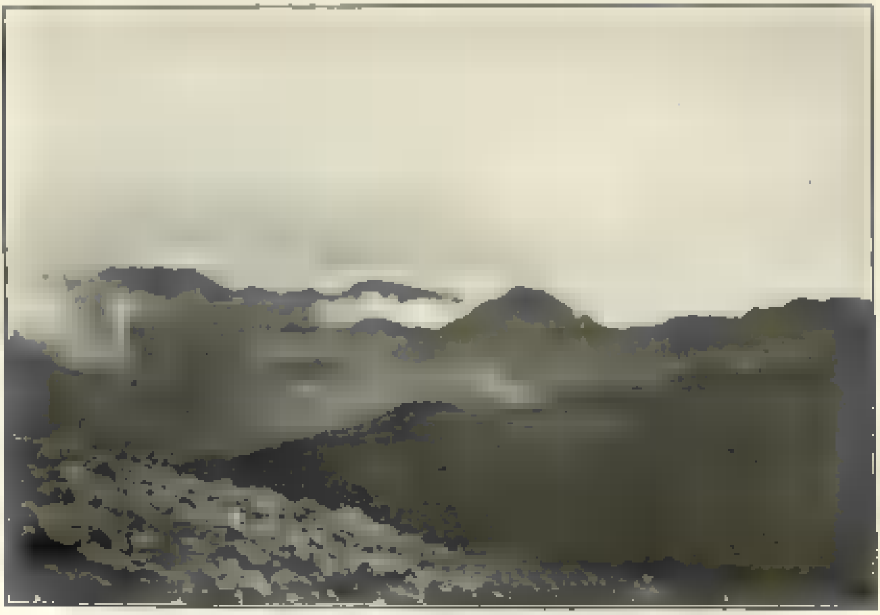
Monkey pod at left, royal palms at right, three coconut palms in the distance, manienie (Bermuda grass) in the foreground.

2. A TYPICAL WASTE LAND SCENE.

A road near Honomanu with a tangle of guava and lantana which has taken possession of the soil. In the center a dilapidated bread-fruit tree.

1. SCHOFIELD BARRACKS, IN THE CENTRAL PLATEAU OF OAHU, LOOKING WEST TOWARD THE WESTERN OR WAIANAE RANGE OF MOUNTAINS.

Mount Kaala at the right is the highest point on the island.



2. HALEAKALA CRATER FROM THE WEST RIM.

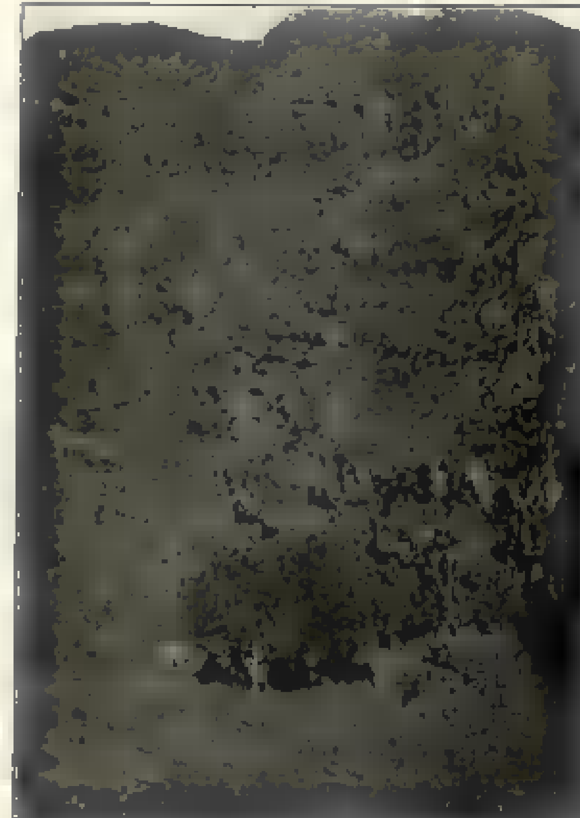
Several smaller cones and craters may be seen within the main crater.

1. MAUNA KEA FROM HUMUULA AT AN ALTITUDE OF 6,700 FEET, LOOKING NORTH, SHOWING THE GRADUAL SLOPE TO THE SUMMIT (13,825 FEET).

2. SOUTHERN MOLOKAI NEAR THE SEA. LOOKING EASTWARD, SHOWING THE EVEN SLOPE OF THE MOUNTAINS.

A belt of algaroba trees in the middle distance.

1. A MOUNTAIN GORGE BACK OF LAHAINA, MAUI, SHOWING THE STEEPNESS OF THE VALLEY SIDES.



2. WEST WALL OF HALEAKALA CRATER.

1. A Grassy Slope Above Nuuanu Pali.

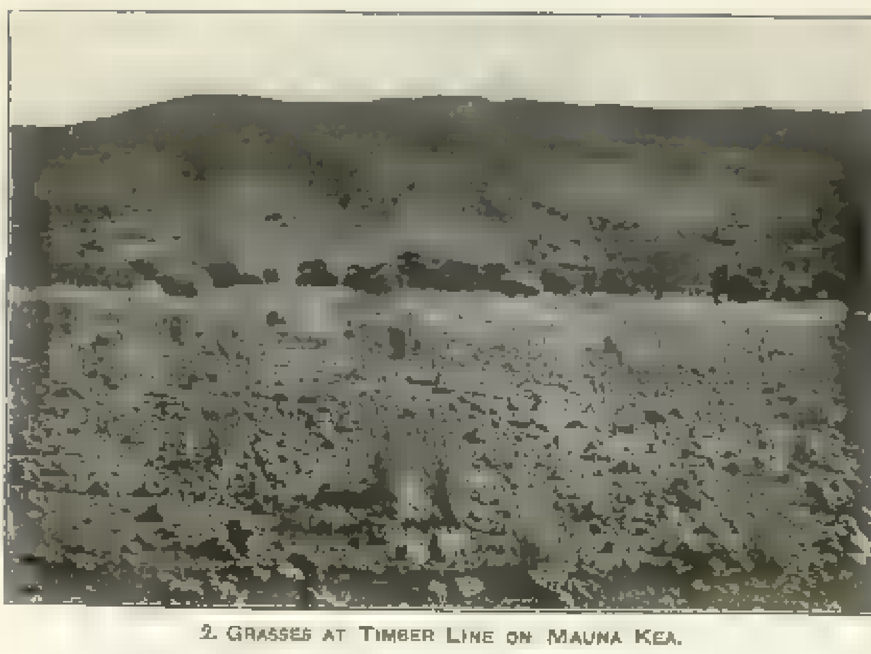
The trade wind is always very strong through this pass. The tufts of grass are *Eragrostis variabilis*.

2. Prickly-Pear Cactus (Opuntia megacantha).

Introduced from Mexico, now common in the drier regions of all the islands.

1. SCHOFIELD BARRACKS, LOOKING EAST TOWARD THE KOOLAU RANGE OF MOUNTAINS.

Papayas in the middle distance; pilipiliula (*Chrysopogon aciculatus*) and other grasses in the foreground.



2. GRASSES AT TIMBER LINE ON MAUNA KEA.

The bunch grass in the foreground is *Agrostis sandwicensis*.

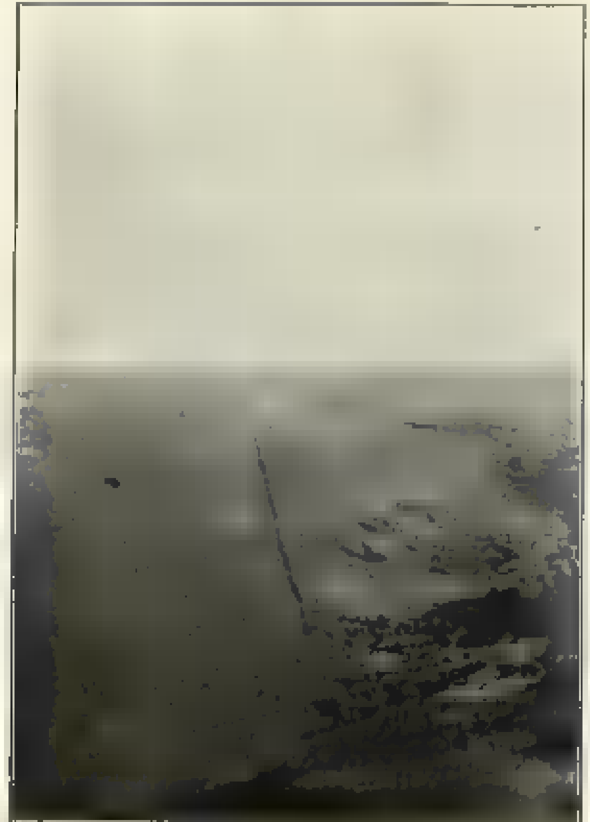
1. GRASSES AT TIMBER LINE ON MAUNA KEA.

The grass with narrow inflorescence is *Koeleria glomerata*; that with feathery inflorescence, *Deschampsia australis*. The trees are mostly mamani (*Sophora chrysophylla*).

2. KUKUI TREES (ALEURITES MOLUCCANA).

The shrubs in the foreground are young kukui plants.

1. KOA TREE ON NORTH SLOPE OF MAUNA KEA. AN ISOLATED SPECIMEN WITH SPREADING TOP.



2. A FIELD OF NATAL GRASS OR NATAL REDTOP (TRICHOLAENA ROSEA) ON THE MOLOKAI RANCH.

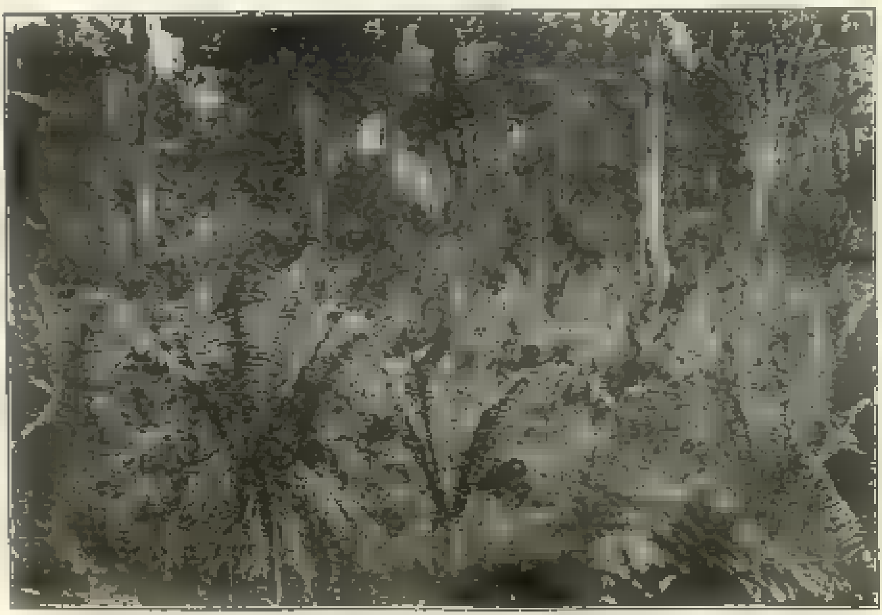
The part to the right of the fence has been allowed to reach maturity. The part of the left has been grazed.

1. A YOUNG PLANT OF KOKIA DRYNARIOIDES ON THE GROUNDS OF MR. M. C. COOKE, MOLOKAI.

This species has become extinct as a wild plant. A few small trees have been grown from seed from the last plant known.

2. ARBORESCENT SPECIES OF PALMLIKE LOBELIACEAE NEAR KAHOLUAMANO, KAUAI.

1. A FOREST OF KOAIA (ACACIA KOAIA) ON THE SOUTHWESTERN SLOPES OF THE KOHALA MOUNTAINS.



2. A HEAVY GROWTH OF FERN (DRYOPTERIS FUSCOATRA) IN THE HUMID FOREST ON THE SLOPES OF THE HUALALAI MOUNTAINS.

1. A CINDER SLOPE IN HALEAKALA CRATER.

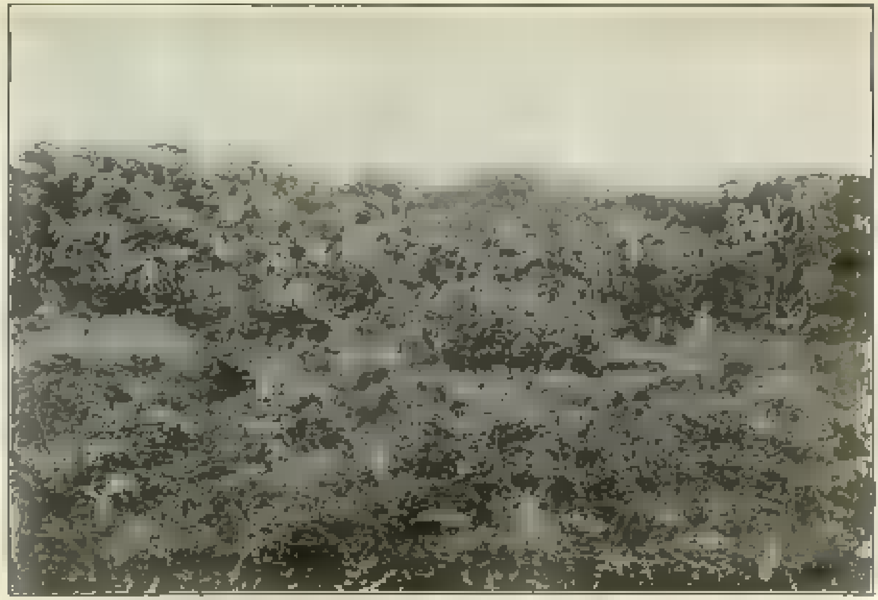
The white points near the top of the slope are plants of silver sword.

2. SILVER SWORD (ARGYROXIPHIUM SANDWICENSE), A STERILE PLANT BROUGHT DOWN FROM THE UPPER SLOPES OF MAUNA KEA. OUR PART-HAWAIIAN GUIDE.

1. CHARACTERISTIC MOUNTAIN FOREST NEAR KAHOLUAMANO.

The tree trunks are white and glisten in the distance.

2. TREE FERNS (CIBOTIUM MENZIESII) AT THE UNITED STATES EXPERIMENT STATION, GLENWOOD, HAWAII.



1. A SMALL OPEN BOG NEAR KAHOLUAMANO, KAUAI. FOREST IN BACKGROUND.

2. A SMALL LAKE NEAR THE SUMMIT OF MAUNA KEA, ALTITUDE ABOUT 13,000 FEET.

Because of the porous lava soil lakes or ponds are rare.

1. TWO CHARACTERISTIC SPECIES FROM THE OPEN BOG AT THE SUMMIT OF PUU KUKUI, WEST MAUI.

The plants were brought down and photographed at camp near the lower edge of the rain forest. Mr. G. C. Munro, manager of the Lanai Ranch, is holding in his left hand *Lobelia gaudichaudii*, in his right *Wilkesia grayana*.

2. A LEAF OF GUNNERA PETALOIDEA BROUGHT DOWN TO IDLEWILD FROM THE HUMID FOREST ALONG THE OLINDA PIPE LINE, EAST MAUI, ON THE NORTH SLOPE OF HALEAKALA.

THE SOCIAL, EDUCATIONAL, AND SCIENTIFIC VALUE OF BOTANIC GARDENS.[1]

By Prof. John Merle Coulter.

It is a noteworthy fact that the United States is beginning to appreciate botanic gardens. This appreciation may be relatively superficial as yet, but the superficial is usually the preliminary step that leads to the fundamental. The desirability of botanic gardens was not obvious when large areas in a state of nature were available to almost every one; but when we developed congested populations in cities and made artificial most of our open areas, the thought of botanic gardens began to take form.

Those of you who have traveled in Europe must have been impressed by the multiplicity of such gardens. They began there in the form of monastic gardens, in which the so-called "simples," used in primitive medicine, were cultivated. Then they came out into the open as city gardens, chiefly for the enjoyment of the people and to beautify the city. Finally, they became also scientific, and gradually led to such great establishments as the botanic gardens at Rome, Geneva, and Paris, the great modern gardens on the outskirts of Berlin and Munich, and that greatest of all garden establishments, the Kew Gardens of London. These are but conspicuous illustrations of what almost every European city had developed before we began to think of garden establishments.

I wish to speak of three conspicuous contributions that such an establishment can make, not all of which are appreciated as they should be. There is no better audience for this purpose than the friends and supporters of the Brooklyn Botanic Garden, which has achieved more in certain directions than any other garden in the country. I wish you to realize, not only that your support is justified, but also that perhaps you have builded better than you knew. I shall speak of these three contributions in what I conceive to be the inverse order of their importance, in the sense that the superficial, however desirable, is less important than the fundamental.

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[1] Address delivered at the dedication of the laboratory building and plant houses of the Brooklyn Botanic Garden, Apr. 19, 1917. Reprinted by permission from Science, June 29, 1917, N. S., vol. 45, No. 1174.

1. The first is the *social* contribution. "Social" is a very inclusive word. Anything that contributes to the welfare of a community in any way is a social contribution. In this sense, the results of education and of religion are also social. I am using the word in no such general sense, however, but simply to include the betterment of city conditions for living.

A botanic garden is a social contribution because it is one answer to the problem of congestion. It is not sufficient to have open spaces, even when those spaces are beautified as parks. There can not be too many of these, but something more is needed. I wonder if you all appreciate what the touch of nature means. It is something more than open space for breathing. It is a kind of elixir that helps men to be *men*. The garden is a museum of nature, not merely an area left to nature. In it there are assembled the representatives of many regions, so that it gives a world contact. It is a great service to give any community the opportunity of such a contact.

The contact with nature presently develops the contact of interest; and interests outside the routine of living, when these interests are worth while, are both curative and stimulating. Then when interest is awakened, and plants are examined as individuals, and not merely as a general population, the wonders of plant life begin to appear. I wonder how many know why leaves are green and flowers colored; why some plants are trees and others herbs; why some trail and climb, and others stand erect. All of this vegetation is the natural covering of the earth, which cities have eliminated. It is the covering that makes your lives and all life possible. I should say, therefore, that the mere presence of a botanic garden in a city is like having the spirit of nature as a guest, and all who become acquainted with this spirit are the better for it.

There is nothing more artificial than city life, and therefore nothing more abnormal. Some are able now and then to renew their contact with the natural and normal, but most are not. A botanic garden brings to the many a touch of what only the few can secure for themselves. You have doubtless developed some very definite and effective ways of expressing the social contribution of this garden to the life and welfare of this community. But to me, speaking in general terms, the conspicuous *social* contribution is to provide the opportunity, and see to it that all the people take advantage of it.

2. The second is the *educational* contribution. It is this contribution to the community that you have developed with remarkable success. Nature is a great teacher when she really comes in contact with the pupil. The notion is too prevalent that knowledge comes from books—that one can read *about* nature and acquire knowledge *of* nature. One might just as well try to acquire knowledge of business by reading about business. Knowledge comes from experience,

from contact. We must distinguish between *knowledge* and *information*. Knowledge is first-hand, obtained from actual contact with the material. Information is secondhand, hearsay, coming from no actual experience. Reading *about* nature, therefore, brings information; contact *with* nature brings knowledge. To serve a community by bringing its children into contact with nature is a great educational service.

Perhaps the most significant contact with nature is the handling of plants. We are seeking now for an army of people with some experience in handling plants; for more people who will cultivate plants wherever space permits. You have been made to realize, in these days of testing our resources, that the most important material problem we are facing as a nation is the problem of food production and conservation. Food production has lagged far behind population, and this increasing gap must be closed up. Our science of transportation has far outstripped our science of food production, so that we have come to depend not only upon a diminishing food supply but also upon transporting that supply across a continent. To learn to grow plants and to grow them everywhere, especially near our great centers of population, is a crying need.

The development of home gardens, therefore, is not merely a service for social betterment that all recognize, but it is becoming more and more a public necessity. Any institution that gives you and your children this training is not merely an educational institution but also a public benefactor. A botanic garden doing such work is like a power house, radiating energy throughout the community. Such training is an equipment which not only enriches life but it is also an equipment for service. In providing such an opportunity a city can do nothing better for its young people and its homes and, through them, for itself.

These two contributions, social and educational, seem very obvious, but the third contribution needs fuller explanation.

3. The third is the *scientific* contribution. This I regard as your great opportunity, and I wish to help you realize it. We are a very practical people, and unless we can see immediate returns from an investment, we decline to undertake it. Very few people appreciate what it has taken to make things practical. We speak of fundamental science and practical science; sometimes we call these two phases pure science and applied science. The general impression is that pure science holds no relation to public welfare, and that applied science serves our needs. You should know that all applied science depends upon pure science; that there would be nothing to apply unless pure science had discovered it. If we had only applied science, it would soon become sterile. It is pure or fundamental science that keeps applied science alive, that makes progress possible. For ex-

ample, if Faraday had not worked in pure science, Edison would have had no basis for his wonderful inventions. And so it is throughout the whole range of the practical things we are using to-day. To neglect pure science and support only applied science would be like wanting children and eliminating parents. When I hear those who are regarded as practical men lauding our practical achievements, which certainly deserve praise, but speaking lightly of work in fundamental research, I think of them as those who would praise the practical electric light and forget the impractical, because unseen, power house. Scientific research is the power house that generates all the energy we apply in developing what may be called the machinery of our civilization.

I wish now to indicate, by a single illustration, how such an institution as this may become a great laboratory for public service. My illustration is intended only to indicate how fundamental research is of the greatest service to public welfare, a source of energy to be called upon and applied as needs arise. It is not intended to indicate the specific kind of work that any given garden should undertake; this may well vary, but it is a good illustration of the value of research work in general.

I have indicated the problem of food production that our nation is facing to-day. In some way our food production must overtake our population. Over a century ago certain men were speculating about evolution. The subject of evolution was not a science, because men were *meditating* rather than *investigating*. Certainly nothing could have seemed further removed from general human interest than this speculation. About a century ago speculation about evolution merged into the science of evolution when men began to observe the facts upon which such a theory could be based. For a century, observation and inference went on until they had reached the limit of usefulness. Near the beginning of this century, men concluded that the only way to secure further progress was to test by experiment whether one kind of plant could actually produce another kind. In observing the behavior of plants in breeding, they began to uncover the laws of heredity; and as knowledge of these laws increased, it became evident that this knowledge could be applied to the practical handling of plants, and what we call our revolution in agriculture followed. It is a far cry from a speculation about evolution to the solution of our food problem, but the continuity is unbroken. It is by such essential and generally unrecognized service that scientific research is contributing to human welfare. I wish to be more specific and to indicate some of the ways in which science has solved this food problem.

Through scientific work in the study of heredity we have learned to multiply the races of our useful plants so that they may fit in more

exactly to the variable conditions in which plants must be grown. It is a curious fact that we have been blind so long to the teaching of nature that conditions for plants are not the same everywhere. We have always realized that the natural vegetation of this country is not a monotonous covering. Every change in vegetation indicates a special set of conditions for plant growth, and yet we have been trying to grow the same races of plants everywhere. The result has been that we have gotten maximum returns from some areas, minimum returns from others, and medium returns from the rest. Our total result has been an average. By multiplying races of plants to fit conditions more closely, our total result will not be an *average*, but a *maximum* everywhere. This one suggestion of science will double our production.

One of the most destructive enemies of our crops is drought. On the average our production is cut in half by this enemy. Scientific investigation has shown that it is possible to develop drought-resistant races of all our useful plants. This means the possibility, not only of insuring our crops against drought where they are now cultivated, but also of increasing enormously the area of cultivation, by adding the so-called arid regions of perpetual drought.

Another destructive enemy of our valuable crops is disease. The Government has expended millions of dollars in the study of plant diseases, in the hope of reducing the loss. The scientific work of recent years has shown that it is possible to breed disease-resistant races. Plants, like human beings, differ in their susceptibility to diseases. Some are immune, and others are susceptible. This means that we can cultivate immune races and let the susceptibles perish. We cannot handle human diseases in this way. Before what we speak of as the wonderful advance of medicine, we were unconsciously practising selection of the human race for immunity. The susceptibles disappeared and the immunes survived. Now medicine has been so successful that it saves the susceptibles and keeps them mixed with the immunes, so that our human problem is more difficult than it used to be. But we have no such sentiment about plants, and we can cultivate immunity and eliminate susceptibility.

I am told by those who are trained in collecting such statistics that if these suggestions of scientific research can be generally applied, our food production will overtake our population. It is in such ways that the results of science find application. This is not merely a local service, but a national service, and in such a time as this it is a patriotic service.

May I recall your attention to the work of the National Research Council in connection with your opportunity. This council has been appointed by the National Academy of Sciences at the request of President Wilson. Its purpose is to bring into cooperation all of our

scientific equipment in an attack upon the problems we are facing. This week we have been canvassing the problems that need immediate attention, and they are to be assigned to various research centers, where properly trained men and adequate equipment are available. I want to include this institution in these assignments. Your opportunity is an unusual one, for already you have many things that are needed. You have the opportunity to respond to this call from your country, and to see to it that research is properly provided for. Such research work not only provides what are called the sinews of war, when war becomes necessary, but it also means progress and power in time of peace. It is this opportunity that led me to say earlier in this address that perhaps you have builded better than you knew.

Do not be misled into thinking that only those problems should be attacked that have been developed by some immediate need. Research is like the exploration of a new country. It must be traversed throughout; all trails must be followed and mapped. Some trails will lead to rich lands and valuable mines; others will not. No one can tell until everything has been explored. Your research work here should mean an exploration of nature as represented by plants, and there is no more important region of nature. The more we know about plants the more intelligent we become in handling them. I have known scientific explorers who discovered a new country and mapped it, but no one at the time recognized it as good for anything. Years afterwards it was discovered that it was rich in possibilities.

Years ago an Austrian monk, working in his monastery garden, discovered some interesting behavior in the plants he was breeding. He recorded his facts and his conclusions in an obscure journal, and no one paid any attention to it. What could be expected from a monk pottering in his garden? Years afterwards the contribution was discovered, and to-day it is the basis of most of our work in the study of heredity, and this in turn has made our agriculture scientific. No one knows what may turn up in a garden like this one of yours. It is a gold mine of opportunity. See to it that it is cultivated.

THE BIRD ROOKERIES OF THE TORTUGAS.

By PAUL BARTSCH,
Curator, Marine Invertebrates, U. S. National Museum.

[With 38 plates.]

Look at a map of the southeastern United States and you will note a string of islands swinging south, then bending more and more westward at some little distance off the peninsula of southern Florida. These are the Florida Keys, a part of which in reality represents an ancient barrier reef long since elevated above the surface of the sea. Some of these keys are mere barren sand banks, while others are clothed with tropical vegetation. Quite a number of these islands have recently been joined by the fills and viaducts of the over-sea portion of the Florida East Coast Railway which connects Key West with the mainland, and promises to produce profound changes in the topography of the region. This chain of keys terminates in the Tortugas Atoll, the scene of our story, some 65 statute miles west of Key West.

The elevated portions of the atoll at present are East, Middle, and Sand Key, of the middle eastern perimeter; Long, Bush, Bird, Garden Key of the southwestern rim; and Loggerhead Key on the southwestern border. Formerly two other keys, Northeast Key and North Key, of the northeastern edge, were conspicuous elevated elements above the sea's surface, but they have long since been swept away by the waves. Of the existing keys, Middle and Sand Key are mere heaps of piled up sea organisms and their fragments, without vegetation. Bush Key now appears as an elevated coral reef with piles of organic detritus heaped up in spots, but likewise barren of vegetation. East Key supports a dense growth of Bermuda grass on the flattened, upper elevated portion, with a scattered growth of scaevola bushes and other plants. A somewhat similar condition obtains on the southern end of Long Key, but the vegetation is less abundant and more scattered, while the northern end consists of a barren rim of coral boulders that curves eastward and southward, to join with the reef fringe of Bush Key. Garden Key is almost completely inclosed by the walls of Fort Jefferson. The portion outside of the wall is overgrown with crab grass and the long trailing vines of the

sea bean and the moon vine and the goat-foot morning-glory, while within the wall several species of palms and a grove of buttonwood, Cordia trees and ornamental shrubs furnish a favorite retreat to the many lesser migratory birds. Bird Key has an almost dead fringe of bay cedars and a few coconut palms near the house and a scattered, scant growth of cactus and grass, as well as a few ornamental shrubs near the buildings. The largest of the keys is Loggerhead Key, the center of which is occupied by Loggerhead Light, a first-class, revolving, flashing beacon that projects a beam for more than 18 miles, and the buildings necessary to quarter the attendants. On the west central portion is a boat shed and pier, while the east central portion is provided with another pier and landing stage. On the northern end of the island the buildings of the Marine Biological Laboratory of the Carnegie Institution are nestled in a growth of palms, maritime pines, and flowering shrubs, fringed on the sea side by bay cedars, Tournefortias, and Bermuda grass. Excepting the introduced palms, figs and other ornamental plants about the laboratory and the light, the most conspicuous vegetal features of the island are the bay cedars, which practically girdle, and in many places completely cross it. These attain a height of more than 10 feet. This covering of bay cedars is irregularly interrupted by grassy meadows, where the short crab grass and spear grass vie with the flat-leaved cactus for supremacy. The scattered huge agaves south of the lighthouse usually rear some flowering stalks, which furnish a favorite resting place for the hawks during the migratory season. A Cordia grove occupies the east shore line a little north of the light, and here and there groups of ashy leaved Tournefortias lend a funereal aspect to the beach. In places, dense growths of Bermuda grass occur immediately above the reach of the storm tide and wave their abundant, shimmering heads of seeds in a most pleasing manner. In other regions, similar reaches are covered by a fuzzy, brown-topped sedge, while still other places are measured by the long trailing vines of the goat-foot morning-glory (*Ipomaea pes-caprae*), the moon vine (*Calonyction tuba*), and the sea bean (*Canavali lineata*).

The most interesting island of the group is Bird Key, for of the 32,810 birds listed for the group in last summer's census, 31,200 center about this key. In the list given below the numbers in italic refer to Bird Key inhabitants.

A numerical list of the summer birds of the Tortugas.

(Based upon observations made between July 19–31, 1917.)

Laughing gull		2
Royal tern		24
Roseate tern ....estimated	adult	200
	young	300

Least tern	estimated	adult	800
		young	600
Sooty tern	estimated	adult	[1] 18,000
		young	[2] 7,200
Black tern			24
Noddy tern	estimated	adult	[1] 4,000
		young	[2] 1,600
Booby			3
Red-footed booby			1
Brown pelican			4
Man-o'-war bird			400
Ward's heron			1
Green heron			1
Least sandpiper			20
Sanderling			1
Black-bellied plover			6
Semipalmated plover			2
Ruddy turnstone			20
Osprey			1
			32,610

These rookeries were first brought to the attention of ornithologists by John James Audubon, who, in his masterful ornithological biographies, gives us an account of a visit to these keys in May, 1832. W. E. D. Scott, in his paper "On birds observed at the Dry Tortugas, Florida, during parts of March and April, 1890,"[3] gives us the first list of birds noted in the group, while Dr. Joseph Thompson, United States Navy, in 1903 described "The Tortugas tern colony" in the fifth volume of Bird Lore.[4]

It is safe to state that the most intensive scrutiny to which a wild bird colony has been subjected was made upon the birds of Bird Key by Dr. John B. Watson, professor of experimental and comparative psychology at the Johns Hopkins University, and Dr. K. S. Lashley, while a Johnston scholar in psychology at the same institution. These gentlemen subjected the terns to exhaustive psychoanalyses with the hope of throwing light on the problem of the homing instinct. In getting at the basic data underlying this problem they found it necessary to study the various phases of the activities displayed by the birds in and about the island. The results of their splendid efforts are embodied in a series of papers from which I shall take the liberty to quote at some length.[5, 6]

[1] Based upon Doctor Watson's census of 1908.

[2] An estimate admitting two-fifths as many offspring as we had parents.

[3] The Auk, vol. 7, pp. 301–314.

[4] Bird Lore, vol. 5, pp. 73–84.

[5] "The Behavior of Noddy and Sooty Terns," John B. Watson, Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, vol. 2, No. 103, 1908, pp. 189–255.

[6] "Homing and Related Activities of Birds," papers from the Dept. of Marine Biology of the Carnegie Institution of Washington, vol. 7, No. 211.

It is the homing instinct of birds that renders the Tortugas the most interesting group of all the Florida Keys, for here no less than four species of terns perform their housekeeping, and two of these, namely, the sooty and noddy tern, are not known to breed in any other part of the United States.

Most of our birds leave their place of birth as soon as they have attained sufficient strength to roam. Many of them perform remarkable journeys in their annual migration from the breeding grounds to their winter home in the fall; and when the breeding season approaches and the reproductive instinct asserts itself they go back to the breeding grounds in the spring.

The late Prof. W. W. Cooke, has shown that the golden plover and the arctic tern dwell alternately in the Arctic and in the Antarctic, performing a journey of over 11,000 miles twice a year. He has pointed out that the golden plover in one flight covers a distance of 2,400 miles without a stop.

Unlike man, who seems ever ready to shift his tent to where he is afforded the most favorable conditions for existence, most birds cling tenaciously to the immediate surroundings in which they were cradled when it comes to a selection of a nesting site.

This fact was first demonstrated by sea birds known to breed on certain islands, and on these only. More recently it has also been shown that many of the lesser birds cling equally persistently to their nesting site and it has been found that some not only seek the same general region, but the same shelf of rocks and even the same nest year after year.

Look at a good hydrographic chart (pl. 1) and you will note that the Tortugas, though situated on the shallow continental shelf, are on the extreme outer limit thereof, away out in the Gulf of Mexico, removed from the murky waters of the southward drift that constitutes the coastal waters of the peninsula, and in a little less degree that bathing the upper keys. Here we have the clear water of the Gulf Stream and the first clear water shallows available for a spawning ground to the fishes of the Gulf. The presence of an enormous number of small fish fry at the proper season was, probably more than any other factor, the determining cause in the selection of this site for the rookery by the ancestors of the enormous tern colonies that breed here. It is also quite possible that the factor determining the time of arrival and departure of the birds may depend upon the migration and spawning season of the fish used by these birds as food.

When not on the breeding grounds, the noddy and sooty terns roam in small groups over the waters to the south of our islands. I have met them on both coasts of Cuba and Haiti, where they can be

seen fishing as they are wont to do in the Tortugas, or resting on floating driftwood, sand beaches, or low, rocky ledges, but in March or April (the time seems to vary in different years, as shown by the table below) the homing instinct seizes them and they head for their favorite island of the Tortugas group.

Table showing dates of arrival and departure.

(Data furnished by the Biological Survey, U. S. Department of Agriculture, whose warden protects the colony from eggers.)

Year.	Arrival.	Departure.
1907	Apr. 27	Sept. 22.
1909		Aug. 15–27.
1910	Apr. 27	
1911	Apr. 14–May 6	Aug. 6–Sept. 28.
1912	Mar. 20	Aug. 26–Sept. 20.
1913	Apr. 8	Aug. 21–Sept. 12.
1916	Apr. 15	

Watson and Lashley, in speaking of the Bird Key rookery, 1915, page 61, say:

> The terns breed in great numbers upon Bird Key. * * * Their nests, of which there were more than 10,000 in 1908, are in many cases closely crowded together, as many as 30 sooty nests being found in an area of 100 square feet, and the nests and eggs are almost indistinguishable to the human observer. Indeed, the island suggests a city of 10,000 houses, all much alike, unnumbered, and set down at random, without streets or definite landmarks. The birds choose their own nests, without error, from among hundreds of similar ones, and under normal conditions never show the slightest hesitation in making their choice.

I will now consider, one by one, the various species in the order of their numerical representation. I shall use freely the data furnished by Audubon, Watson, and Lashley in the discussion of the various forms.

THE SOOTY TERN (*Onychoprion fuscatus*).

By far the largest number of breeding birds on the Tortugas belong to this species, of which probably more than 25,000 are present on Bird Key at the close of the breeding season.

Our earliest record of this colony was furnished by that master of ornithological biography, John James Audubon.[1] The description which he gives us of the colony, based upon a visit during the early part of the last century, is extremely interesting. The rareness and inaccessibility of the volume demands a full quotation in order that an adequate comparison may be had with the now existing conditions. We therefore quote the following:

> Early in the afternoon of the 9th of May, 1832, I was standing on the deck of the United States revenue-cutter the Marion. The weather was very beautiful,

[1] Ornithological Biography, vol. 3, pp. 263–269. 1835.

although hot, and a favourable breeze wafted us onwards in our course. Captain Robert Day, who stood near me, on looking toward the south-west, ordered some person to be sent to the top to watch the appearance of land. A young lad was instantly seen ascending the rigging, and not many minutes after he had attained his post, we heard from him the cry of "land." It was the low keys of the Tortugas, toward which we had been steering. No change was made in the course of the "Lady of the Green Mantle," who glided along as if aware of the knowledge possessed by her commander. Now the light-house lantern appeared like a bright gem glittering in the rays of the sun. Presently the masts and flags of several wreckers showed us that they were anchored in the small but safe harbour. We sailed on, and our active pilot, who was also the first lieutenant of the Marion, pointed out to me a small island [Bird Key] which he said was at this season the resort of thousands of birds, which he described by calling them "Black and White Sea Swallows," and again another islet, [Bush Key] equally well stocked with another kind of Sea Swallow, which he added were called Noddies, because they frequently alighted on the yards of vessels at night, and slept there. He assured me that both species were on their respective breeding-grounds by millions, that the eggs of the first lay on the sand under bushes, at intervals of about a foot, while the nests of the last were placed as thickly on the bushes of their own chosen island. "Before we cast anchor," he added, "you will see them rise in swarms like those of bees when disturbed in their hive, and their cries will deafen you."

You may easily imagine how anxious I was to realize the picture; I expressed a wish to be landed on the island; but the kind officer replied, "My good Sir, you will soon be tired of their incessant noise and numbers, and will enjoy the procuring of Noddies much better." After various tacks, we made our way through the curious and extremely dangerous channels leading to the small harbour, where we anchored. As the chain grated the ear, I saw a cloud-like mass arise over the "Bird Key" from which we were only a few hundred yards distant; and in a few minutes the yawl was carrying myself and my assistant ashore. On landing, I felt for a moment as if the birds would raise me from the ground, so thick were they all round, and so quick the motion of their wings. Their cries were indeed deafening, yet not more than half of them took to wing on our arrival, those which rose being chiefly male birds, as we afterwards ascertained. We ran across the naked beach, and as we entered the thick cover before us, and spread in different directions, we might at every step have caught a sitting bird, or one scrambling through the bushes to escape from us. Some of the sailors, who had more than once been there before, had provided themselves with sticks, with which they knocked down the birds as they flew thick around and over them. In less than half an hour, more than a hundred Terns lay dead in a heap, and a number of baskets were filled to the brim with eggs. We then returned on board, and declined disturbing the rest any more that night. My assistant, Mr. H. Ward, of London, skinned upward of fifty specimens, aided by Captain Day's servant. The sailors told me that the birds were excellent eating, but on this point I cannot say much in corroboration of their opinion, although I can safely recommend the eggs, for I considered them delicious, in whatever way cooked, and during our stay at the Tortugas we never passed a day without providing ourselves with a good quantity of them.

The next morning Mr. Ward told me that great numbers of the Terns left their island at two o'clock, flew off towards the sea, and returned a little before day, or about four o'clock. This I afterwards observed to be regularly the case, unless there happened to blow a gale, a proof that this species sees as well during the night as by day, when they also go to sea in search of food

for themselves and their young. In this respect they differ from the *Sterna stolida*, which, when overtaken at sea by darkness, even when land is only a few miles distant, alight on the water, and frequently on the yards of vessels, where if undisturbed they sleep until the return of day. It is from this circumstance that they have obtained the name of Noddy, to which in fact they are much better entitled than the present species, which has also been so named, but of which I never observed any to alight on a vessel in which I was for thirty-five days in the Gulf of Mexico, at a time when that bird was as abundant during the day as the other species, of which many were caught at my desire by the sailors.

The present species rarely alights on the water, where it seems incommoded by its long tail; but the other, the *Sterna stolida*, which, in the shape of its tail, and in some of its habits, shows an affinity to the Petrels, not only frequently alights on the sea, but swims about on floating patches of the Gulf Weed, seizing on the small fry and little crabs that are found among the branches of that plant, or immediately beneath them.

I have often thought, since I became acquainted with the habits of the bird which here occupies our attention, that it differs materially from all the other species of the same genus that occur on our coasts. The *Sterna fuliginosa* never dives headlong and perpendicularly as the small species are wont to do, such as *St. hirundo*, *St. arctica*, *St. minuta*, *St. Dougallii*, or *St. nigra*, but passes over its prey in a curved line, and picks it up. Its action I cannot better compare to that of any other bird than the Night Hawk, while plunging over its female. I have often observed this Tern follow and hover in the wake of a porpoise, while the latter was pursuing its prey, and at the instant when by a sudden dash it frightens and drives toward the surface the fry around it, the Tern as suddenly passes over the spot, and picks up a small fish or two.

Nor is the flight of this Tern characterized by the buoyancy and undecidedness, if I may so speak, of the other species mentioned above, it being as firm and steady as that of the Cayenne Tern, excepting during the movements performed in procuring its food. Like some of the smaller gulls, this bird not unfrequently hovers close to the water to pick up floating objects, such as small bits of fat pork and greasy substances thrown overboard purposely for making the experiment. It is not improbable that the habits peculiar to this species, the Noddy, and one or two others, of which I shall have occasion to speak elsewhere, may tend to induce systematic writers to place them in a new "subgenus."

There is a circumstance connected with the habits of the two species of which I now more particularly speak, which, although perhaps somewhat out of place, I can not refrain from introducing here. It is that the *Sterna stolida always forms a nest on trees or bushes*, on which that bird alights with as much ease as a Crow or Thrush; whereas the *Sterna fuliginosa* never forms a nest of any sort, but deposits its eggs in a slight cavity which it scoops in the sand under the trees. But, reader, let us return to the Bird Key.

Early the next morning I was put on shore, and remained there until I had completed my observations on the Terns. I paid no attention to their lamentable cries, which were the less piercing that on this occasion I did not molest them in the least. Having seated myself on the shelly sand, which here formed the only soil, I remained almost motionless for several hours, in consequence of which the birds alighted about me, at the distance of only a few yards, so that I could plainly see with what efforts and pains the younger females deposited their eggs. Their bill was open, and their pantings indicated their distress, but after the egg had been expelled, they immediately walked off in an awkward manner, until they reached a place where they could arise

without striking the branches of the bushes near them, when they flew away. Here and there, in numerous places within twenty yards of me, females, having their complement of eggs, alighted, and quietly commenced the labour of incubation. Now and then a male bird also settled close by, and immediately disgorged a small fish within the reach of the female. After some curious reciprocal nods of their heads, which were doubtless intended as marks of affection, the caterer would fly off. Several individuals, which had not commenced laying their eggs, I saw scratch the sand with their feet, in the manner of the common fowl, while searching for food. In the course of this operation, they frequently seated themselves in the shallow basin to try how it fitted their form, or find out what was still wanted to ensure their comfort. Not the least semblance of a quarrel did I observe between any two of these interesting creatures; indeed, they all appeared as if happy members of a single family; and as if to gratify my utmost wishes, a few of them went through the process of courtship in my presence. The male birds frequently threw their heads over their back as it were, in the manner of several species of gulls; they also swelled out their throats, walked round the females, and ended by uttering a soft puffing sound as they caressed them. Then the pair for a moment or two walked round each other, and at length rose on wing and soon disappeared. Such is one of the many sights it has been my good fortune to witness, and by each of them have I been deeply impressed with a sense of the pervading power of the Deity.

The Sooty Tern always lays three eggs as its full number, and in no instance, among thousands of the nests which were on the Bird Key, did I find one more when the female was sitting close. I was desirous of ascertaining whether the male and the female incubate alternately; but this I was unable to do, as the birds frequently left their eggs for half an hour or even three-quarters at a time, but rarely longer. This circumstance, together with the very slight difference in size and colour between the sexes, was the cause of my failure.

It was curious to observe their actions whenever a large party landed on the island. All those not engaged in incubation would immediately rise in the air and scream aloud; those on the ground would then join them as quickly as they could, and the whole forming a vast mass, with a broad extended front, would as it were charge us, pass over for fifty yards or so, then suddenly wheel round, and again renew their attack. This they would repeat six or eight times in succession. When the sailors, at our desire, all shouted as loud as they could, the phalanx would for an instant become perfectly silent, as if to gather our meaning; but the next moment, like a huge wave breaking on the beach, it would rush forward with deafening noise.

When wounded and seized by the hand, this bird bites severely, and utters a plaintive cry differing from its usual note, which is loud and shrill, resembling the syllables oo-ee, oo-ee. Their nests are all scooped near the roots or stems of the bushes, and under the shade of their boughs, in many places within a few inches of each other. There is less difference between their eggs, than is commonly seen in those of water birds, both with respect to size and colouring. They generally measure two inches and one-eighth, by one and a half, have a smooth shell, with the ground of a pale cream colour, sparingly marked with various tinges of lightish umber, and still lighter marks of purple, which appear as if within the shell. The Lieutenant, N. Lacoste, Esq., informed me that shortly after the young are hatched, they ramble pell-mell over the island, to meet their parents, and be fed by them; that these birds have been known to collect there for the purpose of breeding, since the oldest wreckers on that coast can recollect; and that they usually arrive in May, and remain until the beginning of August, when they retire southward to spend the winter months.

I could not however obtain a sufficiently accurate description of the different states of plumage which they go through, so as to enable me to describe them in the manner I should wish to do. All that I can say is, that before they take their departure, the young are grayish-brown above, dull white beneath, and have the tail very short.

At Bird Key we found a party of Spanish Eggers from Havannah. They had already laid in a cargo of about eight tons of the eggs of this Tern and the Noddy. On asking them how many they supposed they had, they answered that they never counted them, even while selling them, but disposed of them at seventy-five cents per gallon; and that one turn to market sometimes produced upwards of two hundred dollars, while it took only a week to sail backwards and forwards and collect their cargo. Some eggers, who now and then come from Key West, sell their eggs at twelve and a half cents the dozen; but wherever these eggs are carried, they must soon be disposed of and eaten, for they become putrid in a few weeks.

On referring to my journal once more, I find the following remarks with reference to the Sooty Tern. It would appear that at some period not very remote, the Noddy, *Sterna stolida*, must have had it in contemplation to appropriate to itself its neighbour's domains; as on examination of this island, several thousand nests of that bird were found built on the tops of the bushes, although no birds of the species were about them. It is therefore probable that if such an attempt was made by them, they were defeated and forced to confine themselves to the neighbouring island, where they breed by themselves, although it is only a few miles distant. That such interferences and conflicts now and then occur among different species of birds, has often been observed by other persons, and in several instances by myself, particularly among Herons. In these cases, right or wrong, the stronger party never fails to dislodge the weaker, and keep possession of the disputed ground.

Soon after the birds arrive on the island a nesting site is sought. Dr. Watson gives a most graphic account of this. I shall therefore let him speak.

My observations began late one afternoon, before any eggs had been laid. Hundreds of the birds were grouped together, incessantly fighting and screaming. It quickly became apparent that most of them had chosen a nest site and were defending it against all late comers. Both male and female were present. Each pair in this particular locality defended a circular territory, roughly 14 inches to 2 feet in diameter. Other birds in wandering around would stumble into this sacred territory and a fight would ensue. The fights would often lead to encroachments upon the territory of still other birds. The number of those fighting would thus be constantly increased. I have seen as many as 14 sooties thus engaging in a fight. Birds 10 and 15 feet away would rush into the fight and the noise and confusion beggared description. Sometimes as many as 10 or 15 such fighting groups could be observed in the area of 1,000 square feet. Quiet would momentarily ensue and then be broken by another series of fights. During the choice of the nesting site the fights continue day and night, with only intermittent periods of quiet.

Of the actual nest construction he tells the following:

The actual construction of the nest, when a nest structure is formed, begins after an undefended area has been found. The process of nest building is somewhat as follows: The bird puts the breast to the ground, thereby supporting the body and leaving the legs comparatively free. The feet are used as a con-

bined scraper and shovel. A few backward strokes of the feet are made, which serve both to loosen the sand and to remove it from beneath the body. The bird then turns slightly and repeats the process. When it has turned 360° (or less) it begins to use the breast as a shaper. By continuing this process, the depression is soon made to assume the required diameter and depth. My notes show that the bay cedar leaves are often gathered up and placed around the rim of the nest as the hole is being dug. I can not say which sex does the work, but I believe that both male and female engage in it. As soon as the depression is made, both birds begin to defend it. Naturally, where no nest is made, the nest site alone is chosen and defended as described above.

An approximate count of the total number of the sooty nests was made in 1908 in the following way: Those parts of the surface of the island containing nests were subdivided into 10 separate areas. The number of square feet in each area was next determined. The average number of nests (spots where eggs were deposited) per square foot was then determined separately for each area. By means of these data, the total (approximate) number of nests on the island was found to be 9,429. Multiplying by two, as in the previous case, we have 18,858 as the total number of adult sooties. It may be said that the above determination was made late in the breeding season, after all the eggs had been laid. It may also be of interest to note that in localities where the nests are very numerous they often are not more than 10 to 12 inches apart.

Plates 5, 6, 8 show the disposition of the nests, for each bird in the picture is occupying his home.

The sooty usually lays but one egg, though occasionally two are deposited. Watson found only 25 nests containing more than one egg in all the thousands examined and but a single one in which two birds were actually hatched and reared. On plate 8 are figured five eggs selected to show the greatest range of color variation observed, for although the general type of coloration is very similar, a considerable diversity is found to be present when one actually searches for variations from the typical form which is represented by the figure.

Watson gives us an intimate picture of the changes that take place in the habits of the adult bird during the various stages of the cycle that begins with nest building and probably ends with the birds leaving the island. He has with infinite patience worked out the daily life routine, with all of its vicissitudes, of the young bird from the time it breaks from the shell until it finds its wings. I shall therefore let him speak.

The general disposition of the sooty, like that of the noddy, changes after the egg is laid and in the same way. Some of them become far bolder than the noddies in a corresponding situation. It was possible for me to lie down within a few inches of a brooding sooty and have it remain on the nest indefinitely. If the hand is extended toward the sooty it will attack vigorously, but I have never had a group of flying sooties attack me as I approached the vicinity of their nests, as was sometimes the case when I ventured too near the nests of the noddies. The birds are very variable in this respect. When one approaches a neighborhood containing many nests, the majority of the birds will fly up into the air, circling round and round, screaming all the while. If one remains quiet, the birds will gradually return and cover the eggs. Gradually

the nests nearest one's position will be cautiously approached and then occupied. A certain small percentage of the birds will remain on the nest, no matter how violent the disturbance.

It appears * * * that the shift at the nest is roughly a diurnal one, but that at times it may not occur except once in 48 hours. * * * Apparently most of the shifts are made at night. I attempted on many occasions to determine the hour of shifting by leaving a lantern near the nest and making observations during the night, but the light could not be arranged so as not to frighten the birds, and their reactions consequently were not natural. The birds would refuse to cover their eggs if the light were made intense enough to be of value to me.

Watson tells us that observation on 16 marked nests proved that the period of incubation for the sooty is 26 days. We continue to quote from him:

During the first three days after the appearance of the young, the sooty is reluctant to leave the young and nest on disturbance. Later the adults fly away at the slightest disturbance, much as they do during the "laying" season. It is interesting to observe at every disturbance of a nesting place how quickly the ground will be deserted by both young and old, after the young have reached the age of 3 days. As they leave, the alarm cry is sounded and the commotion spreads to all the near-by nests. When quiet is restored the birds again alight near the nest and gradually approach it. The young birds meantime have run to the bushes, where they remain motionless after sticking their heads into the crotch of some bush or depressing the body against any convenient solid object. The protective coloring of the young sooties is marked. When motionless, as above suggested, they are difficult to find. When the adult returns to the nest, the young birds gradually come from their hiding places at the peculiar clucking call of the parent. The parents (after the first few days) recognize their own offspring with ease and accuracy, often going to meet them as they emerge from the bushes. * * *

The adult would circle over the area and give a call; it would be answered and random movements would give place to direct. The bird would steer immediately for the source of the call. By peculiar chuckling sounds, which are emitted at this period when mates return, one can be sure that the proper nest has been located. I observed this many times during one evening. After the young were 20 to 30 days old I have heard the young birds answer the call of the parent back and forth a dozen times before the latter actually alighted.

Neither young nor old is quiet during this period of the nesting season. On the contrary, the noise is practically doubled. In addition to the ordinary sounds made by the adults and the new cries which are added at this time, there is present the high-pitched, insistent "peep-peep" of the young terns. Momentarily the sounds of the adults will cease and the cries of the little ones remind one very strongly of a poultry yard on a tremendous scale.

Though the parents feed the young at any hour of the day, feeding can be most easily observed at dusk. It has already been mentioned that the sooties hurry home at nightfall in great numbers. From 4 until 8 p. m. this feeding process keeps the island in commotion. The feeding of the young birds has many interested spectators. While I have never seen the terns from the neighboring nests, which may be observing the process, attempt to rob the young bird, I judge from the actions of the feeding parent that such is occasionally the case. If the parent happens to disgorge more than the young tern can take into its

beak and the food is allowed to fall to the ground, it is ludicrous to watch the rapidity with which the parent picks up the food and reswallows it. Oftentimes the mate of the feeding parent is near; its rôle is a purely passive one except when the "spectators" attempt to approach too near. Its part is then to assist in warding them off. * * *

The parents alternately feed the young, but instead of a diurnal period of feeding, such as the parents have before the appearance of the young, the intervals vary anywhere from four to seven hours. * * *

The care of the young, especially from 20 days on, must be an exhausting process for the parents. They become emaciated and somewhat bedraggled in appearance. This is not to be wondered at when we consider that a healthy young sooty can eat anywhere from 20 to 40 minnows of no insignificant size in a day. It may be of general interest to note that after the first few days the parent always recognizes and feeds its own young and no others, and furthermore, the young tern recognizes its own parents and attempts to feed only from them. Never but once out of many thousands of observations did I see a young tern begging food from a stranger.

Watson and Lashley have shown conclusively by a large series of experiments that the sooty tern seems to entertain man's legal aspect of property rights.

Many attempts were made to shift nests to the edge of the beach with the purpose of transferring them to rafts in the hope of ultimately transplanting a part of the colony to other keys, but however slowly such shifts were made (6 inches or so per day) the nests were either abandoned when moved 4 feet or less from their original position, or the eggs were rolled back as fast as they could be moved forward.

On the other hand, a vertical elevation of the nest to a considerable height did not cause its abandonment, as shown by the following experiment made by Watson:

A nest was chosen in an open space, but very close to some bushes. I obliterated the nest as the bird had constructed it, inserted a black pan, filled this with sand, and constructed a nest inside of it. This gave me an opportunity to move the nest *upward* as well as laterally. On returning, the bird alighted on the nest without showing any signs of disturbance. An hour later I came back and pulled the pan out of the sand and put a few sticks under it. The bird returned, but was not disturbed by this slight change. I then drove in four stakes 10 centimeters high and mounted the pan thereon. This served to raise the nest upward without disturbing the other relations of the nest. The bird on returning *alighted immediately on nest*. The other birds gathered around, craning their necks and peering upward. The bird then stood up and came to the edge of the pan and peered down. This seemed to disturb it and it flew to the ground, but hopped up again immediately, covered the egg and sat there in comfort the rest of the day. Raising the nest 10 centimeters in the air requires almost no adjustment on the part of the bird. On account of a storm on the island, which lasted for two days, no further experiments were made at this time on this nest. I next raised this nest 100 centimeters; *bird alighted immediately squarely on the top of the nest*; did not make a false movement. On craning neck over the edge of the pan a little later, however, became disturbed and alighted on the ground, and remained there for 45 minutes without attempting again to get on nest. I forced the bird to fly up. Again

alighted on the nest and began to brood the egg in comfort. On my return several hours later it was still sitting quietly on nest.

On the second day after this (when this same bird was at the nest again) I lowered the nest back to 30 centimeters, its first vertical position. On returning the bird alighted squarely on the nest, making perfect adjustment. I scared the bird away. On its return the bird again adjusted accurately. I next moved the nest back to the height of 100 centimeters. Bird returned and alighted on egg and adjusted to it before I could get back to my position in the bushes. Adjustment in the vertical plane is made with exceeding rapidity and ease.

I then moved the nest 100 centimeters to the east, leaving it 100 centimeters above the ground. Behavior of bird very interesting. Would not alight on nest. Alighted at the former ground position. After a long time flew from the old position and up to new position of nest. Immediately hopped down and began a most peculiar performance. *Bird would hover in space, attempting to adjust to the nest in the air at its former position and height.* It would then fly away again and come back to the old position and try to alight in space. This was done 20 times. At the end of 20 minutes the bird alighted upon the pan in its new position and sat down on egg. I then scared the bird away 5 successive times, to see if it would alight immediately upon the pan. Each time on returning the bird alighted at the old ground position and proceeded from this point to the new position of the nest.

I then put the pan back in its old position. Bird returned and alighted on pan immediately. In this position I then raised the pan to a height of 200 centimeters. This raised the nest well up above any of the surrounding bushes. This did not cause the bird the slightest disturbance. I forced it to make three or four adjustments to the nest in immediate succession. It made them all with equal precision.

Watson tells us that the habit which he has called the sunning reaction in the noddies, while present to some extent before the appearance of the young, shows itself in completed form as the development of the young progresses. He also states that he has never seen sooties roosting upon stakes and buoys, etc., but that "the sooty always leaves the island and returns to it without at any time having ceased its flight. This seems rather remarkable when we take into account the fact that the sooty leaves the island in the early morning and oftentimes does not return until toward nightfall."

At times, however, they do rest in elevated positions, as shown in plate 4, in which a group of sooties is occupying the tops of a bunch of bay cedars.

When flying low over the water to the fishing ground the sooty resembles the black skimmer in its flight to such a remarkable degree that I have very often been forced to pick up my glass in the hope of listing this bird for the Tortugas region. The fishing is done by quickly picking up such small fry as may be forced to jump above the surface by pursuing larger fish. The birds may be seen fishing singly or sometimes a hundred or more of both noddies and sooties

may be present. The number usually depends upon the size of the harassed school of fish.

As to the nocturnal activities of the birds, Watson states:

From other observations, too numerous to mention separately, I conclude that all birds return to the island at night. Many times just at sundown I have come from Loggerhead Key to Bird Key. The terns are coming in by hundreds and thousands, flying low over the water. By the time twilight has faded the water is entirely deserted. Several trips made to Fort Jefferson late at night showed that these birds do not leave the island at night. The moment the island is reached, however, no matter at what hour of the night, one finds the sooties busily flying from one place to another on it.

An interesting pastime of the sooties is described by Watson.

The sooties often soar round and round, getting higher and higher until lost to sight. They usually join the frigate birds in this reaction. I am inclined to think that the sooty when sufficiently fed spends a large part of its time in such maneuvers.

It will circle in the air again and again, giving out the shrill nasal alarm cry of ëăh, ëăh, ëăh. It is the most restless and noisy bird I know, and almost as much so at night as during the day. Sleep apparently is taken during both day and night by dozing momentarily at intervals. How the bird maintains its vigor with no more continuous rest than it takes is a mystery. This peculiarity of the sooty has led to the popular nickname of "wide-awake tern."

THE NODDY TERN (*Anoüs stolidus*).

Here, as in the case of the sooty tern, we are indebted to Audubon for the first account of this colony. I shall quote what he has to tell us of his experience with these birds on the Tortugas in 1832. This sketch is the more interesting on account of the fact that the birds no longer breed upon the key (Bush Key) on which he found them nesting, as all the vegetation, in fact, most everything shiftable above the sea, has long since been swept away by the waves. His reference to noddy nests on Bird Key mentioned in his sooty tern biography shows that noddies had built nests in the bay cedars of that key, although he states that they were not occupied at the time of his visit. Since then the colony has been forced to make a complete shift and the choice between Bird and Loggerhead Key has fallen to the former, where Watson estimated the presence of 1,400 adult birds in 1908. We shall now quote from Audubon.

About the beginning of May, the Noddies collect from all parts of the Gulf of Mexico, and the coasts of Florida, for the purpose of returning to their breeding places, on one of the Tortugas called Noddy Key. They nearly equal in number the Sooty Terns, which also breed on an island a few miles distant. The Noddies form regular nests of twigs and dry grass, which they place on the bushes or low trees, but never on the ground. On visiting their island on the 11th of May, 1832, I was surprised to see that many of them were repairing and augmenting nests that had remained through the winter, while others were employed in constructing new ones, and some were already sitting on their

eggs. In a great many instances, the repaired nests formed masses nearly two feet in height, and yet all of them had only a slight hollow for the eggs, broken shells of which were found among the entire ones, as if they had been purposely placed there. The birds did not discontinue their labours, although there were nine or ten of us walking among the bushes, and when we had gone a few yards into the thicket, thousands of them flew quite low over us, some at times coming so close as to enable us to catch a few of them with the hand. On one side might be seen a Noddy carrying a stick in its bill, or a bird picking up something from the ground to add to its nest; on the other several were seen sitting on their eggs unconscious of danger, while their mates brought them food. The greater part rose on wing as we advanced, but re-alighted as soon as we had passed. The bushes were rarely taller than ourselves, so that we could easily see the eggs in the nests. This was quite a new sight to me, and not less pleasing than unexpected.

The Noddy, like most other species of Terns, lays three eggs, which average two inches in length, by an inch and three-eighths in breadth, and are of a reddish-yellow colour, spotted and patched with dull red and faint purple. They afford excellent eating, and our sailors seldom failed to collect bucketfuls of them daily during our stay at the Tortugas. The wreckers assured me that the young birds remain along with the old through the winter, in which respect the Noddy, if this account be correct, differs from other species, the young of which keep by themselves until spring.

At the approach of a boat, the Noddies never flew off their island, in the manner of the Sooty Terns. They appeared to go farther out to sea than those birds, in search of their food, which consists of fishes mostly caught amid the floating sea-weeds, these Terns seizing them, not by plunging perpendicularly downwards, as other species do, but by skimming close over the surface in the manner of Gulls, and also by alighting and swimming around the edges of the weeds. This I had abundant opportunities of seeing while on the Gulf of Mexico.

The flight of this bird greatly resembles that of the Night Hawk when passing over meadows or rivers. When about to alight on the water the Noddy keeps its wings extended upwards, and touches it first with its feet. It swims with considerable buoyancy and grace, and at times immerses its head to seize a fish. It does not see well by night, and it is perhaps for this reason that it frequently alights on the spars of vessels, where it sleeps so sound that the seamen often catch them. When seized in the hand, it utters a rough cry, not unlike that of a young American Crow taken from the nest. On such occasions, it does not disgorge its food, like the Cayenne Tern and other species although it bites severely with quickly repeated movements of the bill, which, on missing the object aimed at, snaps like that of our larger Fly-catchers. Some which I kept several days refused all kinds of food, became dull and languid, and at length died.

While hovering over us near their nests, these birds emitted a low querulous murmur, and, if unmolested, would attempt to alight on our heads. After a few visits, however, they became rather more careful of themselves, although the sitting birds often suffered us to put a hat over them. Like the Sooty Tern, this species incubates both day and night. The differences exhibited by Terns with respect to their mode of nestling and incubation, are great, even in the same neighbourhood, and under the same degree of atmospheric temperature. This species breeds on bushes or low trees, placing several nests on the same bush, or in fact as many as it will hold. The *Sterna fuliginosa* scoops out a slight hollow in the sand, under the bushes, without forming any nest, and in-

cubates closely like the former. The Sandwich, the Cayenne, and the Roseate Terns, drop their eggs on the sand or the bare rock, and seldom sit upon them until evening, or during cloudy or rainy weather. The Cayenne, Sooty and Noddy Terns differ greatly in their flight, their manner of feeding, and the extent of their migrations. The tail of the Noddy is cuneate, instead of being forked, in which respect it differs essentially from that of the other species. Perhaps the naturalists who placed it in the same genus with the Roseate Tern may have been nodding over their books.

The several years of study by Watson and Lashley have added much to our knowledge of this species, and I shall take the liberty to quote from them extensively in order to render the picture as complete as possible.

Of the mating, Watson states:

My notes contain a rather full account of a striking series of reactions between two noddies which I took to be a case of mating and choice of nest site, but since it occurred late in the season and did not lead to a completed nest, I advance it tentatively.

One day I observed several noddies "sunning" upon the wire covering of one of my large experimental cages. Suddenly, one of the birds (male) began nodding and bowing to a bird standing near (female). This nodding reaction is one of the most interesting and ludicrous acts of the Noddy Tern. It is quite elaborate. Two birds will face each other, one will then bow the head almost to the ground, raise it quickly almost to a vertical position, and then quickly lower it. He will repeat this over and over again with great rapidity. The other bird goes through a similar pantomime. If a stranger bird alights near the group, he salutes those nearest, and is in turn saluted by them. During the pantomime a sound is rarely made. The female gave immediate attention and began efforts to extract fish from the throat of the male. The male would first make efforts to disgorge, then put the tip of the beak almost to the ground and incline it to the angle most suitable to admit her beak. She would then thrust her beak into his (the ordinary feeding reaction). The feeding reaction was alternated with the nodding. After this series of acts had been repeated 20 times, the male flew off and brought a stick. He deposited this near the female and then again offered to feed her. She again tried to feed, then the male attempted sexual relations. She immediately flew away, but almost immediately returned and alighted at a slightly different place. The male again brought the stick and again bowed and offered to feed her. She accepted the food, but again flew away when the male attempted to mount her. At this juncture the island was disturbed and my observations could not continue.

The noddy constructs its nest from (1) loose dead branches of the bay cedar bushes; (2) of seaweed; (3) of a combination of these; (4) of a combination of either or both of these with various kinds of sea shells and coral. When the shells and coral are employed, they are often placed as an inner lining to the nest and the egg is deposited directly upon them. The nest itself is a quite variable structure, and usually loosely put together. It is very shallow, and this is rather singular, since the wind often blows the egg or the young to the ground.

The nests remaining from year to year are utilized by the birds at successive nesting periods; whether or not by the same pair can not with certainty be answered at present. On account of this utilization of the old nest from

year to year, some of the oldest nests have grown to enormous size, due to the addition of new materials at each successive season.

Both birds work, bringing sticks, seaweed, shells, and coral. Both birds shape the nest clumsily by pecking and pulling at the sticks. They never weave the sticks so as to form a compact and durable nest. The stick is dropped on the rim, then drawn into position. Frequently, first one bird, then the other, sits in the nest and shapes it. In order to do this the bird rises on its feet and depresses its breast and turns round and round. The material is obtained both far and near. Floating sticks and seaweed are gathered from the water. They frequently alight under the nests of other birds and gather up the fallen branches. They even take the material from other nests which are left momentarily unguarded. Frequently fights ensue. The birds work neither steadily nor rapidly; 10, 15, 20 minutes elapse before either makes a trip.

Very often the nest has the appearance of being constructed directly upon the ground, but a closer examination usually shows that it has been built upon a tuft of grass or upon the stem of a bush, the branches of which have been broken off close to the ground. The nearest approach I found to the laying of the egg upon the bare ground was in the case of two nests built on a bare horizontal board lying among the cactus growth. In each of these cases the egg was laid directly upon the board, but some dozen or two small sticks retained the egg in position. * * *

While observing the noddies at work upon the nest, it soon became apparent that the daily routine of the female was different from that of the male. From many hundreds of observations it was also evident that the male feeds the female at more or less regular intervals. * * *

The male returns with a full-laden crop. He alights directly upon the nest or near the female. The female at once shows signs of life, and as they approach each other they begin nodding. Then the male invites the female to feed by putting his beak down in a position convenient to her. She gets the food by taking it directly from the mouth of the male, the male disgorging it by successive muscular contractions of the throat and abdomen. The impression one gets from this ludicrous performance is that the bird is choking to death. During the whole of the process of feeding a soft, nasal, rattling purr is emitted, presumably by the female. This purring sound is an invariable indication that feeding is taking place. It is to be heard on no other occasion.

After the egg is laid a marked change appears in the behavior of both the male and the female. The birds will attack even a human intruder, and their defense of the nest against their own kind becomes even more strict than before. Oftentimes the birds will sit on the egg and allow themselves to be caught, striking viciously all the while with their long, keen, pointed beaks. Individuals vary greatly in this respect. On my daily rounds, as I approached the vicinity of a group of nests, several noddies would usually advance to meet me, striking viciously at my head. Their attacks would continue until I withdrew. Many times I have had my hat knocked off and the blood brought from my scalp by their vicious attacks.

Still another marked change occurs in the habits of the birds: The male no longer feeds the female. Each bird takes equal turns at brooding the egg. My attention was first called to this while I was watching the habits of the birds before the egg was laid. Several nests in the vicinity of the place of observation already contained eggs. At these nests I was never able to observe the feeding of the female by the male. At this period the two birds become practically automata. Their life is taken up in alternately brooding the egg

and in feeding. The birds spend little or no time together except at night. The one comes to the nest, the other flies away to feed.

The period of incubation varies for the noddy from 32 to 35 days. This fact was determined on the basis of 16 observations. The young began to appear on the island about May 9 (1917).

The young are cared for in the nest until they become strong enough to leave it and live upon the ground. The young birds born in low nests, even at a very early age (20 days and even earlier), clamber from them with alacrity and hide in near-by bushes when danger is imminent. In many cases these young birds can not get back to the nest. Under these circumstances they remain near the nest locality, and the parents on returning first alight on or near the nest and later hop to the ground and feed the young bird. * * *

As the young advance in age (20 days and at all later ages) the parent will readily leave the nest when disturbed. The tendency in this respect is to revert to the behavior exhibited during the egg-laying season.

Examination of the stomach contents of both young noddies and sooties showed the presence of representatives of the two families of fish, *Carangidae* and *Clupeidae*. * * *

The birds fish by following schools of minnows which are being attacked by larger fish. The minnow, in its efforts to escape, jumps out of the water and skims the surface for a short distance. The terns pick off these minnows as they hop up above and over the surface of the water. * * *

The birds feed singly or in groups, usually in groups. The group may be composed of both noddies and sooties and may contain sometimes as many as 50 to 100 individuals. All during the day groups of noddies and sooties may be seen at work. As the minnows cease to jump above the surface of the water, the group disbands and scatters in every direction. An instant later, as an attack is made upon the minnows in some other locality, the birds immediately rush there and renew their feeding. (See plate 21.)

In this connection I would add that I have at such times seen noddies dive for their prey with almost the same vigor that the common and least terns engage in their pursuit.

I will let Watson continue.

Apparently, at the end of two hours the noddy has supplied its needs, for at this time it returns to the island and relieves its mate at the nest. The latter then comes out upon the water and takes, roughly, a two-hour turn at fishing, then likewise returns to the nest. This routine of spending two hours at the nest and two hours on the water is engaged in by all of the noddies during the seasons of brooding and of rearing the young.

Watson and Lashley also record an interesting and rather rare habit.

In 1910 we saw one noddy fly into the water, fold its wings, and begin swimming like a duck. About 10 other noddies joined this one. This is the only occasion upon which we have ever witnessed swimming movements. We have never seen the sooty in the water, except when accident has overtaken it.

There is one rather interesting difference between the habits of the noddy and those of the sooty which may be mentioned here: Every stake, buoy, or possible resting place upon the water is utilized by the noddy. It will sit almost motionless upon any object projecting from the water for long periods of time. This habit of theirs is like that found in the cormorants, boobies, and pelicans which are present in the neighborhood.

Speaking of the sunning habits of the noddy, Watson states:

> Although the reaction is at bottom gregarious * * * the birds are stolidly indifferent to one another's presence. They sit silent, head to the wind, elaborately preening their feathers, pecking first at one toe, then at another. Occasionally when another noddy joins the group a mutual nodding is engaged in which at times for no observable reason ends in a fight. The birds here as elsewhere are silent. It is interesting to note that a definite distance is maintained between birds engaged in this activity. The distance is determined, I believe, by the long diameter of the body of the bird—they must have a free space in which to turn. I have seen 10 to 12 birds upon the comb of the roof of the house separated from one another by distances so regular that the unaided eye can with difficulty distinguish inequalities in the spacing.
>
> At night the two birds usually remain in branches near the nest, but if disturbed, both fly away for a short distance and circle back almost immediately to the nest. In flying at night both the noddy and the sooty break their graceful flight into short, ungraceful, and ill-directed choppy swoops, very similar to the way the nighthawk breaks its flight when flying after dusk.

THE LEAST TERN (*Sterna antillarum antillarum*).

The call for bird plumage with which to decorate feminine hats bade well to exterminate this most diminutive of our terns. Thanks to the good work of the Audubon Society, enough were saved to leave a remnant for restocking. A small colony formerly bred on the southern end of Loggerhead Key, but the persistent efforts of eggers have banished the species from that island. Last year (1916), however, a single pair reestablished itself here and our plate 22 represents these individuals.

The southern sandy end of Long Key boasts of a colony of about 200 pairs.

The nest of the least tern is a mere hollow scraped in the sand in which the two, sometimes three, or very rarely four eggs are placed. Not a bit of lining is used, nor is there a rim of shells or shell fragments placed about the edge of the nest, as is done by some of the other terns. The nests are always scattered, never crowded. The eggs harmonize extremely well with the coloration of the sand and are very difficult to see, even at a distance of 6 feet. It is their shadow that usually relieves them from the sand, and aids in revealing their presence if you walk on the shady side. The young birds are equally well protected by their mottled coloration, and the tiny chaps seem well aware of this, for they will press themselves flatly against the gravel or shelly beach and remain perfectly motionless as long as danger threatens. At such times they are extremely difficult to see, and it is usually the dark eye, though partly closed, that offers the greatest contrast and gives the clue to the whereabouts of the little fellows. It is remarkable how this harmonious coloration effectively appears to eliminate an entire colony from the scene, save the flying, piping, and screeching parents. One may, for example,

pass over the sand flat of Long Key after the young have slipped from their shell, and not see a dozen young birds, but set up your tent on the breeding grounds, and take a station within it, and you will soon see the parents arrive and their call will cause the little fellows to appear on all sides and run up to the parents to accept the dangling minnow from their bill. They seem to be springing from the very ground, for places which you may have carefully scrutinized only a few moments before and passed as sand only, now yield these tiny, animated fluffs of down. A little later the young birds follow the shore line of the beaches, where they indulge in the never-ending occupation of preening the growing feathers, wading, bathing, and occasionally taking a swim. If you surprise them at such a time they will boldly strike out from shore to rapidly place as much distance between you as possible; after a wide detour to the beach, they will make a rapid rush for the cover of the rougher ground or vegetation. Our figures show birds in various stages of development, usually in the hiding place.

The adult least tern, so far as I know, has no enemies while on the breeding ground. The eggs, however, and probably the young are destroyed by the ghost crab (*Ocypoda albicans* Bosc.) (pl. 26). I have seen large members of this species sidle up to the resting terns and in spite of the vigorous wing beating to which they were subjected, force the bird from the place which it was occupying. This persistent annoyance on the part of the crab appears to permit of but one interpretation; that is, that they are after eggs or young fledglings. I have twice found young birds that had escaped with a partially clipped off wing. One of these, almost fledged (pl. 25), had the primary portion of its wing clipped off very recently, for the wing was still bleeding when the bird was found. The young least terns may also fall the prey of the few laughing gulls that frequent the breeding ground during the season, and it is equally possible that the man-o'-war birds occasionally stoop for these tiny morsels.

The fishing of these little terns is a marvelous thing. They are by far the most active and quickest members of the entire group, a bundle of nervous energy. They speed over the shallow lagoon until a place is found where, at this season, small fish fry congregate in countless numbers, then a momentary halt, a headlong plunge, a dive with sufficient force to make you fear for the safety of the bird as he strikes the water, but it is only a moment, and he is back in the air, shivers the water from his feathery dress, talking, meanwhile, in his ever-pleasant chatty way as he heads for his family with his slender shining prey.

I wish that you might spend a couple of hours within my tent on the breeding grounds of these beautiful creatures and watch their

home life; see the pride with which the male comes with the food for his mate, for he provides for her during the incubation period, and note how coyly she accepts it, and listen to the music of their conversation, for the male apparently begins to tell about how he caught it the moment he heads for shore. At times you would be greatly amused to see how he teasingly refuses to relinquish a choice shiner, turning it before her, now on this side, then on the other, ever deftly squirming to keep it from her; such, and many other little tendernesses occasionally observed in creatures of a higher order, are the order of the day. An hour of watching these swallows of the sea gives one a feeling of kinship and materially expands one's sympathies for the larger universe.

THE ROSEATE TERN (*Sterna dougalli*).

Last year (1917) a colony of about 100 pairs of the roseate tern established itself on the rough coral and shell-strewn northeastern end of Long Key. During the time of my visit, the last 12 days of July, no eggs were found, but young in various stages of development from a few days old to individuals just finding their wings. It was interesting to quietly drift up the shallow bay inclosed in the curve of Long and Bush Key and on landing at the northern end, make a rush across the narrow hurricane rampart that connects Long with Bush Key. The outer shoal of this rough portion of the key formed the habitat frequented by the young birds.

The result of such a sudden visit would be to put all of the adult birds in the air screaming a concerted protest to the intruder (pl. 27), while the young birds would execute a quick scramble for shelter or the water. In a few minutes a raft of small birds would be swimming in a compact body at some distance offshore (pl. 32), and of those remaining on land not one would be in sight. A careful hunt, however, would soon reveal them tucked away in the crevices between the coral boulders, sometimes several young birds under a single coral head. When possible they will crawl completely from sight, but if no cover is present, they will content themselves by merely hiding their heads, as shown by our pictures (pl. 29). At times, too, they merely flatten themselves against the rough ground (pl. 30, fig. A). No matter what their position may be, the young birds are always completely in harmony with their surroundings; the coloration of the young birds is in perfect accord with the general color scheme. We have given a number of plates showing the different developmental stages of the bird and its plumage.

THE BLACK TERN (*Chlidonias nigra surinamensis*).

During last summer's visit we found this aberrantly colored member of the sea swallows present on Long Key during my entire stay at

the Tortugas; that is, from July 19 until the end of the month. There were at least two dozen birds varying in plumage from the adult blacks through the checkered of the adolescent to the immature of the year. Their occurrence at this time seems to almost indicate that they might have bred here, but I greatly doubt that this could have been the case, for we have no record of black terns breeding anywhere nearly as far south as this. I also failed to find any signs of nests, which I am sure I should have been able to locate had they been present, for I am thoroughly familiar with their nesting habits in the North.

THE ROYAL TERN (*Thalasseus maximus*).

A few royal terns are always to be found about the Tortugas during the spring and summer months, but we have no record of their breeding here. A bunch of 14 frequented the northern hook of Loggerhead Key on fair days where they would preen and doze for hours at a time, usually during the warmer parts of the day, in which occupation they were frequently joined by an even larger number of least terns. Plate 37, figure B, shows the birds in this place in characteristic poses.

THE MAN-O'-WAR BIRD (*Fregata magnificens rothschildi*).

Until the young noddy and sooty have slipped from their shell, man-o'-war birds are not especially abundant about the Tortugas. It is true, Fort Jefferson, some old stakes and pieces of wreckage on Bird Key, and on the outer reef, furnish desirable resting places for them, and the abundance of fish likewise an adequate food supply, so that there may be a few more birds here at all times than one would see along the rest of the keys, excepting, of course, their roosting place, the little island near New Found Harbor Key and Key West, whose refuse furnishes a never failing food supply.

However, when the young terns begin to appear on the ground, the man-o'-war birds increase in numbers until four to five hundred will be found crowding all the available wreckage on Bird Key (pl. 36), where they augment their finny diet by occasionally swallowing a young tern. I have seen them pick up and fly away with an almost fledged bird. We will, therefore, have to consider the man-o'-war bird an enemy of the tern.

If you come to dislike the man-o'-war bird for his pilfering on the tern rookeries, you soon lose your dislike when you see him on wing, for there is no bird in existence that equals him when it comes to soaring, a feat for which every airman who sees him envies him.

Fort Jefferson, on Garden Key, is an ideal place from which to study his powers of wing. The high wall that circles the structure catches the slightest breeze that may ripple the sea and causes the

air to be upthrust on the windward side, and upon this column of air the man-o'-war birds will poise themselves with such perfect balance that they seem fixed to a certain spot in the sky. A hundred or more birds at a time may be seen thus hanging motionless suspended over the northeast portion of the fort, low down when the wind is slight, and high up when strong, always in the place which suits their powers of adjustment best.

Their power of vision is likewise marvelous. I recall being at work in a shallow stretch of water when a fish broke above the surface, evidently pursued by a larger member of the finny tribe. A brown pelican at once gave chase and almost reached him, as the fish leaped from the water the third time in short intervals, but a man-o'-war bird that had been suspended way up in the air so high as to appear a mere speck, came down with a rush and snatched it almost from the very beak of the pelican. I have many times since enjoyed casting fish out into the water of Key West Harbor to watch the speed with which man-o'-war birds, soaring high up in the air, will notice them and stoop to pick them up without touching a feather or missing a strike. Our plates 33, 34, and 35 show a series of pictures giving different poses, responses to such baiting in Key West Harbor, while plate 36 shows the man-o'-war birds on Bird Key.

At times a superior-winged man-o'-war bird will give chase to a less endowed individual that has captured a fish and worry him until he disgorges it. The pursuing bird will quickly follow the falling fish and snatch it before it reaches the water. The gulls and boobies are similarly parasitized by the man-o'-war.

Dr. Charles H. Townsend, the director of the New York Aquarium, gives an interesting brief account on the homing of the man-o'-war bird, from which the following quotation is taken:

> In the course of a winter's voyage on the U. S. S. *Albatross* in the South Seas, the writer found among the natives of the Low Archipelago many tame frigate birds. The latter were observed on horizontal perches near the houses, and were supposed to be merely the pets of the children who fed them.
>
> They were entirely tame, having been reared in captivity from the nest. As our acquaintance with the people developed, we discovered that the birds were used by them after the manner of homing "pigeons" to carry messages among the islands.
>
> The numerous islands of the Low Archipelago extend for more than a thousand miles in a northwest and southeast direction, and it appears that the birds return promptly when liberated from quite distant islands. They are distributed by being put aboard small vessels trading among the islands. The birds are liberated whenever there is news to be carried, returning to their perches sometimes in an hour or less from islands just below the horizon and out of sight of the home base. Generally they are in no great hurry. As the food of the frigate bird may be picked up almost anywhere at sea, there is no means of ascertaining how much time the bird loses in feeding or trying to feed en route. It may also linger to enjoy its liberty with other frigate birds.

I did not observe tame frigate birds elsewhere in Polynesia, but Mr. Louis Becke, who is familiar with most of the South Sea Islands, says they were used as letter carriers on the [illegible] Islands when he was there in 1882, carrying messages between islands 60 to 80 miles apart. When he lived on Nanomaga, one of these islands, he exchanged two tame frigate-birds with a trader living on Nuitao, 60 miles distant, for a tame pair reared on that island.

The four birds at liberty frequently passed from one island to the other on their own account, all going together on visits to each other's homes, where they were fed by the natives on their old perches. Mr. Becke's pair usually returned to him within 24 to 36 hours. He tested the speed of the frigate by sending one of his birds by vessel to Nuitao where it was liberated with a message at half past 4 in the afternoon. Before 6 o'clock of the same day the bird was back on its own perch at Nanomaga, accompanied by two of the Nuitao birds, which not being at their perch on that island when it was liberated, it had evidently picked up en route. Sixty miles in an hour and a half is probably easy enough for the frigate bird, as in Malayo-Polynesia it is said to have frequently returned a distance of 60 miles in one hour.

It becomes entirely tame and familiar when raised from the nest, and if given liberty returns regularly to its home perch at night.

THE BOOBIES (*Sula leucogastris*) and (*Sula sula*).

Both the booby and the red-footed booby are found in the Tortugas, the first usually predominant. They do not breed here at the present time, having probably been exterminated by the fishermen and eggers, who are said to have been particularly fond of the flesh of the young birds. I have never seen them on any of the islands during my six annual visits, but have always found them seated upon the top or crossbar of the channel stakes. They are usually quite shy; so much so that it is very difficult to approach them sufficiently close to secure a photograph. This summer, however, we found a booby willing to pose, and a number of rather satisfactory pictures were secured, some of which are assembled on plate 38.

Audubon, in volume 3 of his Ornithological Biographies, gives a graphic account of a breeding colony of boobies on the Tortugas. From his description one is almost tempted to believe that in the early part of the past century both the white-bellied and red-footed boobies resorted to these islands for housekeeping, for his description of Booby Island, probably North Key, which has since disappeared, would fit the requirements for a nesting site of the booby, as it agrees well with the character of the nest requirements now used by this species in Cay Verde, Bahamas, the nearest breeding colony. The description of the breeding birds on Noddy Key, probably Bush Key of our charts, would indicate the red-footed booby as far as habits are concerned. The nearest place where this species is known to breed at present, is Cayman Brac, about 120 miles off south central Cuba.

We will now quote from Audubon's observations of the booby colony at the Tortugas:

As the Marion was nearing the curious islets of the Tortugas, one of the birds that more particularly attracted my notice was of this species. The nearer we approached land, the more numerous did they become, and I felt delighted with the hope that ere many days should elapse, I should have an opportunity of studying their habits. As night drew her sombre curtain over the face of nature, some of these birds alighted on the top-yard of our bark, and I observed ever afterwards that they manifested a propensity to roost at as great a height as possible above the surrounding objects, making choice of the tops of bushes, or even upright poles, and disputing with each other the privilege. The first that was shot at, was approached with considerable difficulty; it had alighted on the prong of a tree which had floated and been fastened to the bottom of a rocky shallow at some distance from shore; the water was about four feet deep and quite rough; sharks we well knew were abundant around us; but the desire to procure the bird was too strong to be overcome by such obstacles. In an instant, the pilot and myself were over the sides of the boat, and onward we proceeded with our guns cocked and ready. The yawl was well manned, and its crew awaiting the result. After we had struggled through the turbulent waters about a hundred yards, my companion raised his gun and fired; but away flew the bird with a broken leg, and we saw no more of it that day. Next day, however, at the same hour, the Booby was seen perched on the same prong, where, after resting about three hours, it made off to the open sea, doubtless in search of food.

About eight miles to the north-east of the Tortugas Lighthouse, lies a small sand-bar a few acres in extent, called Booby Island, on account of the number of birds of this species that resort to it during the breeding season, and to it we accordingly went. We found it not more than a few feet above the surface of the water, but covered with Boobies, which lay basking in the sunshine, and pluming themselves. Our attempt to land on the island before the birds should fly off, proved futile, for before we were within fifty yards of it, they had all betaken themselves to flight, and were dispersing in various directions. We landed, however, distributed ourselves in different parts and sent the boat to some distance, the pilot assuring us that the birds would return. And so it happened. As they approached, we laid ourselves as flat as possible in the sand, and although none of them alighted, we attained our object, for in a couple of hours we procured thirty individuals of both sexes and of different ages, finding little difficulty in bringing them down as they flew over us at a moderate height. The wounded birds that fell on the ground made immediately for the water, moving with more ease than I had expected from the accounts usually given of the awkward motions of these birds on the land. Those which reached the water swam off with great buoyancy, and with such rapidity, that it took much rowing to secure some of them while most of those that fell directly into the sea with only a wing broken, escaped. The island was covered with dung, the odour of which extended to a considerable distance leeward. In the evening of the same day we landed on another island, named after the Noddy, and thickly covered with bushes and low trees, to which thousands of that species of Tern resort for the purpose of breeding. There also we found a great number of Boobies. They were perched on the top-branches of the trees, on which they had nests, and here again we obtained as many as we desired. They flew close over our heads, eyeing us with dismay but in silence; indeed, not one of these birds ever emitted a cry, except at the moment when they rose from their perches or from the sand. Their note is harsh and guttural, somewhat like that of a strangled pig, and resembling the syllables, *hork, hork*.

The nest of the Booby is placed on the top of a bush at a height of from four to ten feet. It is large and flat, formed of a few dry sticks, covered and

matted with sea-weeds in greater quantity. I have no doubt that they return to the same nest many years in succession, and repair it as occasion requires. In all the nests which I examined, only one egg was found, and as most of the birds were sitting, and some of the eggs had the chicks nearly ready for exclusion, it is probable that these birds raise only a single young one like the Common Gannet or Solan Goose. The egg is of a dull white colour, without spots, and about the size of that of a common hen, but more elongated, being 2½ inches in length, with a diameter of 1¾. In some nests they were covered with filth from the parent bird, in the manner of the Florida Cormorant. The young, which had an uncouth appearance, were covered with down; the bill and feet of a deep livid blue or indigo colour. On being touched, they emitted no cry, but turned away their heads at every trial. A great quantity of fish lay beneath the trees in a state of putrefaction, proving how abundantly the young birds were supplied by their parents. Indeed, while we were on Noddy Island, there was a constant succession of birds coming in from the sea with food for their young, consisting chiefly of flying-fish and small mullets, which they disgorged in a half macerated state into the open throats of their offspring. Unfortunately the time afforded me on that coast was not sufficient to enable me to trace the progress of their growth. I observed, however, that none of the birds which were still brown had nests, and that they roosted apart, particularly on Booby Island, where also many barren ones usually resorted, to lie on the sand and bask in the sun.

The flight of the Booby is graceful and extremely protracted. They pass swiftly at a height of from twenty yards to a foot or two from the surface, often following the troughs of the waves to a considerable distance, their wings extended at right angles to the body; then, without any apparent effort, raising themselves and allowing the rolling waters to break beneath them, when they tack about, and sweep along in a contrary direction in search of food, much in the manner of the true Petrels. Now, if you follow an individual, you see that it suddenly stops short, plunges headlong into the water, pierces with its powerful beak and secures a fish, emerges again with inconceivable ease, after a short interval rises on wing, performs a few wide circlings, and makes off toward some shore. At this time its flight is different, being performed by flappings for twenty or thirty paces, with alternate sailings of more than double that space. When overloaded with food, they alight on the water, where, if undisturbed, they appear to remain for hours at a time, probably until digestion has afforded them relief.

The range to which this species confines itself along our coast, seldom extends beyond Cape Hatteras to the eastward, but they become more and more numerous the farther south we proceed. They breed abundantly on all such islands or keys as are adapted for the purpose, on the southern and western coasts of the Floridas and in the Gulf of Mexico, where I was told they breed on the sand-bars. Their power of wing seems sufficient to enable them to brave the tempest, while during a continuance of fair weather they venture to a great distance seaward, and I have seen them fully 200 miles from the land.

The expansibility of the gullet of this species enables it to swallow fishes of considerable size, and on such occasions their mouth seems to spread to an unusual width. In the throats of several individuals that were shot as they were returning to their nests, I found mullets measuring seven or eight inches, that must have weighed fully half a pound. Their body beneath the skin, is covered with numerous air-cells, which probably assist them in raising or lowering themselves while on wing, and perhaps still more so when on the point of performing the rapid plunge by which they secure their prey.

Their principal enemies during the breeding-season are the American Crow and the Fish Crow, both of which destroy their eggs, and the Turkey Buzzard which devours their young while yet unfledged. They breed during the month of May, but I have not been able to ascertain if they raise more than one brood in the season. The adult birds chase away those which are yet immature during the period of incubation. It would seem that they take several years in attaining their perfect state.

When procured alive, they feed freely, and may be kept any length of time, provided they are supplied with fish. No other food, however, could I tempt them to swallow, excepting slices of turtle, which after all they did not seem to relish. In no instance did I observe one drinking. Some authors have stated that the Frigate Pelican and the Gulls force the Booby to disgorge its food that they may obtain it; but this I have never witnessed. Like the Common Gannet, they may be secured by fastening a fish to a soft plank, and sinking it a few feet beneath the surface of the water, for if they perceive the bait, which they are likely to do if they pass over it, they plunge headlong upon it, and drive their bill into the wood.

When a Booby has alighted on the spar of a vessel, it is no easy matter to catch it, unless it is much fatigued; but if exhausted and asleep, an expert seaman may occasionally secure one. I was informed that after the breeding season these birds roost on trees in company with the Brown Pelican and a species of Tern, *Sterna stolida*, and spend their hours of daily rest on the sand-banks. Our pilot, who, as I have mentioned in my second volume, was a man of great observation, assured me that while at Vera Cruz, he saw the fishermen there go to sea, and return from considerable distances, simply by following the course of the Boobies.

The bills and legs of those which I procured in the brown plumage, and which were from one to two years of age, were dusky blue. These were undergoing moult on the 14th of May. At a more advanced age, the parts mentioned become paler, and when the bird has arrived at maturity, are as represented in my plate. I observed no external difference between the sexes in the adult birds. The stomach is a long dilatable pouch, thin, and of a yellow colour. The body is muscular, and the flesh, which is of a dark colour, tough, and having a disagreeable smell, is scarcely fit for food.

I am unable to find a good reason for those who have chosen to call these birds *boobies*. Authors, it is true, generally represent them as extremely *stupid;* but to me the word is utterly inapplicable to any bird with which I am acquainted. The Woodcock, too, is said to be stupid as are many other birds; but my opinion, founded on pretty extensive observation, is, that it is only when birds of any species are unacquainted with man, that they manifest that kind of ignorance or innocence which he calls *stupidity*, and by which they suffer themselves to be imposed upon. A little acquaintance with him soon enables them to perceive enough of his character to induce them to keep aloof. This I observed in the Booby Gannet, as well as in the Noddy Tern, and in certain species of land birds of which I have already spoken. After my first visit to Booby Island in the Tortugas, the Gannets had already become very shy and wary, and before the Marion sailed away from those peaceful retreats of the wandering sea-birds, the *Boobies* had become so knowing, that the most expert of our party could not get within shot of them.

The Tortugas are used as a stepping-stone by many of the lesser migratory birds that winter in the West Indies and even farther south. In the northward journey in spring and the southward flight

in autumn, these birds rest here for a varying length of time before continuing their travels. These migratory land birds always show the effect of their stay on these keys, for most of them look entirely different from the trim little creatures which we are accustomed to see on the mainland. The little warblers and even the bobolinks are all fluffed up and ragged and their appearance and motion suggest "the dim gray dawn of the morning after," the after effect of a "night out." They are lacking in shyness and appear quite as careless about their safety as they do about their appearance.

The eagerness with which they take to a pan of fresh water or the dripping of a leaky storage tank leads me to believe that it is the want of fresh water that is responsible for this change of habit. The only regular supply of fresh water that these birds can obtain on any of the keys are the droplets of dew in the early morning hours and that furnished by an occasional shower. This, then, means a full drink and bath in the early morning and a long thirst through the rest of the hot day. The bathing is rather an interesting function under these circumstances. A bird will rest on a clump of sparkling leaflets, beating his wings against them and thereby accumulating sufficient moisture in the course of time to become thoroughly washed. The vireos and flycatchers plunge against the moist foliage, while the swallows merely graze it as they pass by.

No small land birds breed upon the Tortugas, and it has been held that the lack of fresh water is responsible for this. This explanation alone does not appeal to me, for I know of no exposed fresh water upon any of the keys between Miami and the Tortugas, and yet most of them support several or more species of breeding land birds. It seems more likely that the character of the vegetation and its associated insect fauna is more to their liking on some of the other keys, for the predominant floral element in the Tortugas is bay cedar, a plant that forms a scarcely notable feature in the key flora farther north.

Believing that a list of all the birds so far reported from the Tortugas will not be without interest to the reader, I will close this article with it.

In preparing this list I have consulted the registers in the division of birds of the United States National Museum to see what specimens the national collection contains from the Tortugas. Here I found quite a large series of early records made between 1857 and 1864, which appear in the following list in the columns headed by these numbers.

The 1857 column represents birds collected by G. Würdemann while connected with the Coast and Geodetic Survey.

The 1859 column represents specimens collected by Capt. D. P. Woodbury.

The 1859–60 column shows specimens collected by Dr. J. B. Holder, while the 1860 and 1864 columns refer to additional lots of birds donated by Capt. D. P. Woodbury.

In the 1859 column the * followed by a 1 refers to a specimen donated by Jos. C. Clapp, while the one in the 1860 column marked *[1] denotes a specimen donated by Geo. Phillips.

The remaining columns refer to published records from the Tortugas. These are:

The sixth column includes the birds observed during parts of March and April, 1890, by W. E. D. Scott, as reported in the "Auk," vol. VII, no. 4, pp. 301–314, 1890. The records of 1913, 1914, 1915, 1916, and 1917 were made by the author, and were published as follows:

1913. Yearbook No. 12, Carnegie Institution of Washington, pp. 172–175, "Birds observed on the Florida Keys on April 25 to May 9, 1913."

1914. Yearbook No. 13, Carnegie Institution of Washington, pp. 192–195, "Birds observed on the Florida keys from April 20 to April 30, 1915."

1915. Yearbook No. 14, Carnegie Institution of Washington, pp. 197–199, "Birds observed on the Florida Keys and along the railroad of the mainland from Key Largo to Miami, June 17 to July 1, 1915."

1916. Yearbook No. 15, Carnegie Institution of Washington, pp. 182–188, "Birds observed in 1916 in the region of Miami and the Florida Keys from May 15 to June 4, and along the railroad from Key West to Miami on June 24."

1916. Yearbook No. 15, Carnegie Institution of Washington, pp. 170–173, "Fifth annual list of birds observed on the Florida Keys (1917)."

An asterisk indicates that the bird was observed in that year.

The gull-billed tern is reported under the name *Sterna nuttalli* by Nuttall in his Manual of Ornithology of the United States and Canada, Water Birds page 279, 1834, from the Tortugas.

	1857	1859	1859–1860	1860	1864	1890	1913	1914	1915	1916	1917
Herring gull (*Larus argentatus*)			*			*		*			
Laughing gull (*Larus atricilla megalopterus*)	*					*	*			*	*
Gull-billed tern (*Gelochelidon nilotica*)											
Royal tern (*Thalasseus maximus*)						*	*	*	*	*	*
Cabot's tern (*Sterna sandvicensis acuflavida*)			*								
Roseate tern (*Sterna dougalli*)											*
Least tern (*Sternula antillarum antillarum*)						*	*	*	*	*	*
Sooty tern (*Onychoprion fuscatus*)	*	*				*	*	*	*	*	*
Black tern (*Chlidonias nigra surinamensis*)											*

	1857	1858	1859-1860	1870	1881	1890	1913	1914	1915	1916	1917
Noddy tern (*Anous stolidus stolidus*)	*	*				*	*		*	*	*
Black skimmer (*Rynchops nigra*)						*					
Booby (*Sula leucogastra*)						*					
Red-footed booby (*Sula sula*)								*	*	*	*
Gannet (*Sula bassana*)				*							
Anhinga (*Anhinga anhinga*)				*							
Florida cormorant (*Phalacrocorax auritus floridanus*)						*			*		
Brown pelican (*Pelecanus occidentalis*)						*	*	*		*	*
Man-o'-war bird (*Fregata magnificens rothschildi*)	*					*	*	*	*	*	*
Mallard (*Anas platyrhynchos*)				*							
Snow goose (*Chen hyperboreus hyperboreus*)				*							
Blue goose (*Chen caerulescens*)		*									
Glossy ibis (*Plegadis autumnalis*)			*								
American bittern (*Botaurus lentiginosus*)				*							
Ward's heron (*Ardea herodias wardi*)		*		*		*				*	*
American egret (*Herodias egretta*)			*							*	
Snowy egret (*Egretta candidissima candidissima*)		*									
Reddish egret (*Dichromanassa rufescens*)				*							
Louisiana heron (*Hydranassa tricolor ruficollis*)			*								
Little blue heron (*Florida caerulea caerulea*)			*								
Green heron (*Butorides virescens virescens*)		*				*	*			*	*
Black-crowned night heron (*Nycticorax nycticorax naevius*)		*				*		*			
Yellow-crowned night heron (*Nyctanassa violacea*)		*				*					
Limpkin (*Aramus vociferus*)		*		*							
Virginia rail (*Rallus virginianus*)		*									
Sora rail (*Porzana carolina*)	*	*		*	*						
Black rail (*Creciscus jamaicensis*)		*									
Purple gallinule (*Ionornis martinicus*)		*		*							
Florida gallinule (*Gallinula chloropus cachinnans*)						*					
Wilson's snipe (*Gallinago delicata*)				*							
Least sandpiper (*Pisobia minutilla*)		*				*					
Semipalmated sandpiper (*Ereunetes pusillus*)							*				
Sanderling (*Calidris leucophaea*)						*	*				*
Willet (*Catoptrophorus semipalmatus semipalmatus*)									*		
Upland plover (*Bartramia longicauda*)							*				
Spotted sandpiper (*Actitis macularia*)						*	*				
Black-bellied plover (*Squatarola squatarola*)											*
Semipalmated plover (*Charadrius semipalmatus*)					*	*					*
Belted piping plover (*Charadrius melodus*)						*					
Wilson's plover (*Pagolla wilsonia wilsonia*)							*			*	
Ruddy turnstone (*Arenaria interpres morinella*)						*				*	*
White-crowned dove (*Columba leucocephala*)	*										
Ground dove (*Chaemepelia passerina passerina*)									*		*
Turkey vulture (*Cathartes aura septentrionalis*)											*
Marsh hawk (*Circus hudsonius*)							*	*			
Sharp-shinned hawk (*Accipiter velox*)						*	*	*			
Florida red-shouldered hawk (*Buteo lineatus alleni*)						*	*				
Broad-winged hawk (*Buteo platypterus platypterus*)							*				
Duck hawk (*Rhynchodon peregrinus anatum*)						*					
Pigeon hawk (*Tinnunculus columbarius columbarius*)						*	*	*			
Little sparrow hawk (*Cerchneis sparveria paulus*)						*					
Osprey (*Pandion haliaetus carolinensis*)						*	*	*		*	*
Ani (*Crotophaga ani*)	*										
Yellow-billed cuckoo (*Coccyzus americanus americanus*)					*	*		*		*	
Black-billed cuckoo (*Coccyzus erythrophthalmus*)							*				

	1857	1858	1880–1890	1900	1904	1908	1912	1914	1915	1916	1917
Belted kingfisher (*Streptoceryle alcyon alcyon*)		*				*	*	*			
Ivory-billed woodpecker (*Campephilus principalis*)				*							
Yellow-bellied sapsucker (*Sphyrapicus varius varius*)						*					
Chuck-will's-widow (*Antrostomus carolinensis*)				*		*					
Night hawk (*Chordeiles minor minor*)						*				*	
Night hawk (subspecies) (*Chordeiles minor chapmani*)?										*	
Ruby-throated hummer (*Archilochus colubris*)		*				*					
Kingbird (*Tyrannus tyrannus*)						*		*			
Gray kingbird (*Tyrannus dominicensis dominicensis*)					*	*	*	*		*	
Phoebe (*Sayornis phoebe*)					*						
Wood pewee (*Myiochanes virens*)					*					*	
Florida crow (*Corvus brachyrhynchos pascuus*)						*					
Bobolink (*Dolichonyx oryzivorus*)						*	*			*	
Bahama red-winged blackbird (*Agelaius phoeniceus bryanti*)											*
Orchard oriole (*Icterus spurius*)						*		*			
Baltimore oriole (*Icterus galbula*)		*									
Goldfinch (*Astragalinus tristis tristis*)							*				
Savanna sparrow (*Passerculus sandwichensis savanna*)						*					
Grasshopper sparrow (*Ammodramus savannarum australis*)						*					
Rose-breasted grosbeak (*Zamelodia ludoviciana*)					*						
Scarlet tanager (*Piranga erythromelas*)					*	*	*				
Summer tanager (*Piranga rubra rubra*)						*		*			
Cuban cliff swallow (*Petrochelidon fulva fulva*)						*					
Barn swallow (*Hirundo rustica erythrogastra*)					*	*	*			*	
White-bellied swallow (*Iridoprocne bicolor*)						*	*				
Bahaman swallow (*Callichelidon cyaneoviridis*)						*					
Cedarbird (*Bombycilla cedrorum*)					*						
Black-whiskered vireo (*Vireosylva calidris barbatula*)						*					
Red-eyed vireo (*Vireosylva olivacea*)						*					
Yellow-throated vireo (*Lanivireo flavifrons*)						*					
White-eyed vireo (*Vireo griseus griseus*)						*					
Black and white creeping warbler (*Mniotilta varia*)					*	*					
Prothonotary warbler (*Protonotaria citrea*)						*					
Swainson's warbler (*Limnothlypis swainsonii*)						*					
Worm-eating warbler (*Helmitheros vermivorus*)						*		*			
Bachman's warbler (*Vermivora bachmani*)						*					
Blue-winged warbler (*Vermivora pinus*)						*					
Parula warbler (*Compsothlypis americana americana*)					*	*	*	*			
Cape May warbler (*Dendroica tigrina*)					*	*	*	*			
Black-throated blue warbler (*Dendroica caerulescens caerulescens*)						*	*	*			
Myrtle warbler *Dendroica coronata*)					*	*	*				
Magnolia warbler (*Dendroica magnolia*)					*						
Cerulean warbler (*Dendroica cerulea*)						*					
Black-poll warbler (*Dendroica striata*)	*					*	*	*			
Blackburnian warbler (*Dendroica fusca*)					*						
Yellow-throated warbler (*Dendroica dominica dominica*)						*					
Sycamore warbler (*Dendroica dominica albilora*)						*					
Black-throated green warbler (*Dendroica virens*)						*					
Pine warbler (*Dendroica vigorsi*)							*				
Palm warbler (*Dendroica palmarum palmarum*)						*					
Yellow-palm warbler (*Dendroica palmarum hypochrysea*)						*	*	*		*	
Prairie warbler (*Dendroica discolor*)						*		*			

	1857	1859	1859-1860	1880	1884	1890	1913	1914	1915	1916	1917
Ovenbird (*Seiurus aurocapillus aurocapillus*)	...	...	...	...	*	*	...	*	...	...	...
Water thrush (*Seiurus noveboracensis noveboracensis*)	...	...	...	...	*	*	*	...	...	...	...
Grinnell's water thrush (*Seiurus noveboracensis notabilis*)	...	...	...	...	...	*	...	...	...	...	...
Kentucky warbler (*Oporornis formosus*)	...	...	...	...	...	*	...	*	...	...	...
Maryland yellow-throat (*Geothlypis trichas trichas*)	...	...	...	...	*	*	...	...	...	...	...
Florida yellow-throat (*Geothlypis trichas ignota*)	...	...	...	...	...	...	*	*	...	...	...
Hooded warbler (*Wilsonia citrina*)	...	...	...	...	*	*	...	...	...	...	...
Redstart (*Setophaga ruticilla*)	*	...	...	...	*	*	*	*	...	...	...
Catbird (*Dumetella carolinensis*)	...	*	...	...	*	...	*	*	...	...	...
Blue-gray gnatcatcher (*Polioptila caerulea caerulea*)	...	...	...	...	...	*	...	...	...	...	...
Olive-backed thrush (*Hylocichla ustulata swainsoni*)	...	...	...	...	...	...	*	...	...	...	...
Bluebird (*Sialia sialis sialis*)	...	...	...	...	*	...	...	...	...	...	...

NOTE.—Wherever the term Common Tern (*Sterna hirundo*) appears on the following plates, the name Roseate Tern (*Sterna dougalli*) should be substituted.

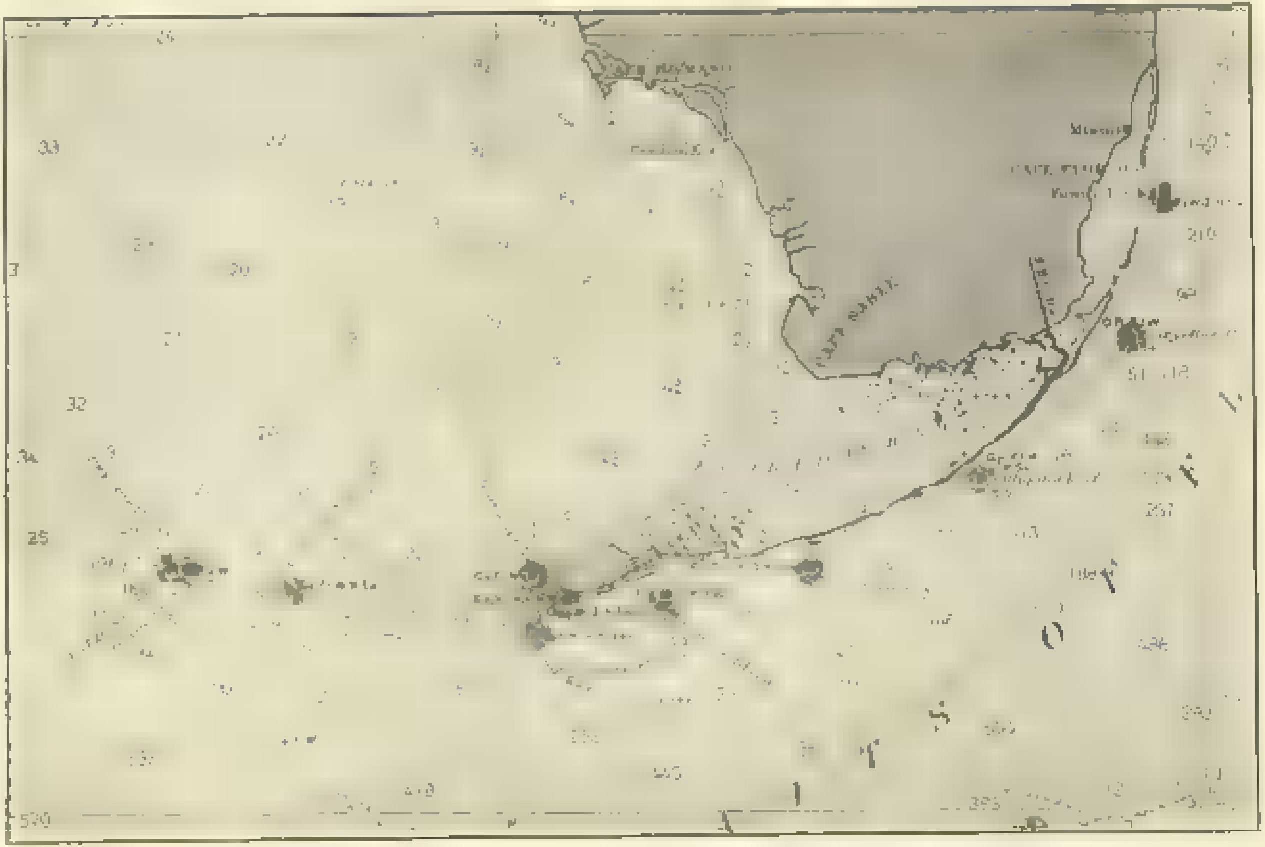


CHART SHOWING SOUTHERN PENINSULA OF FLORIDA AND FLORIDA KEYS. TORTUGAS AT EXTREME LEFT.

BIRD KEY.

A

B

CHARACTERISTIC TERN ACTIVITIES ON BIRD KEY.

A, looks northeast; B, southeast from center of island.

A


B


A. GENERAL VIEW LOOKING NORTHWEST FROM CENTER OF BIRD KEY. B. SOOTY TERNS RESTING UPON TOPS OF BAY CEDARS, A RATHER UNCOMMON PRACTICE.

OPEN GROUNDS NORTHWEST OF THE HOUSE ON BIRD KEY, SHOWING CLOSE DISTRIBUTION OF SOOTIES AND THEIR YOUNG.

BIRD KEY LOOKING NORTHWARD FROM THE HOUSE, SHOWING GENERAL DISPOSITION OF SOOTY TERNS IN OPEN REACHES.

SOOTY TERNS ON THE BREEDING GROUND.

FIVE EGGS OF THE SOOTY TERN, SHOWING RANGE OF VARIATION IN MARKINGS.

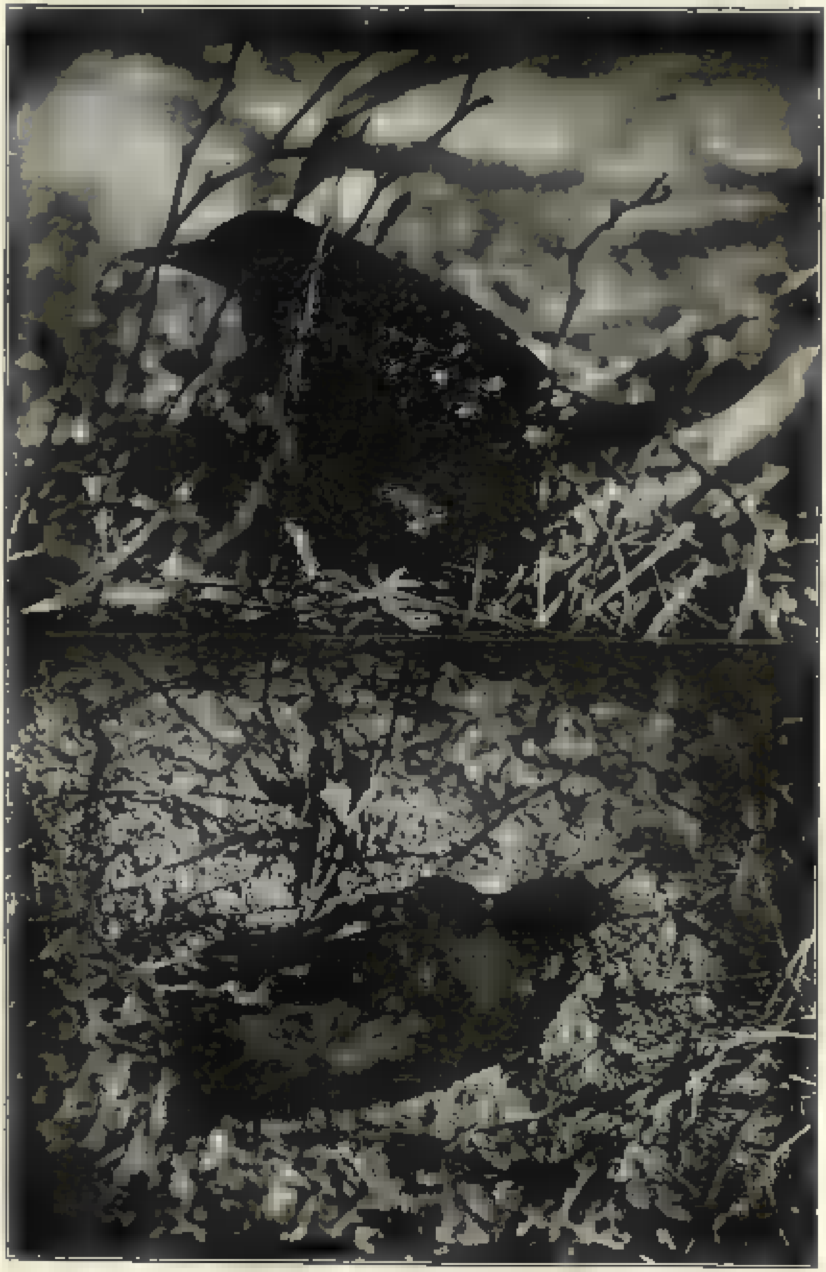
Natural size.

THREE YOUNG SOOTY TERNS SHOWING DEVELOPMENTAL STAGES.

A, about 1 week old; B, more than 1 month old; C, about 25 days old.

A

B



YOUNG SOOTY TERNS.

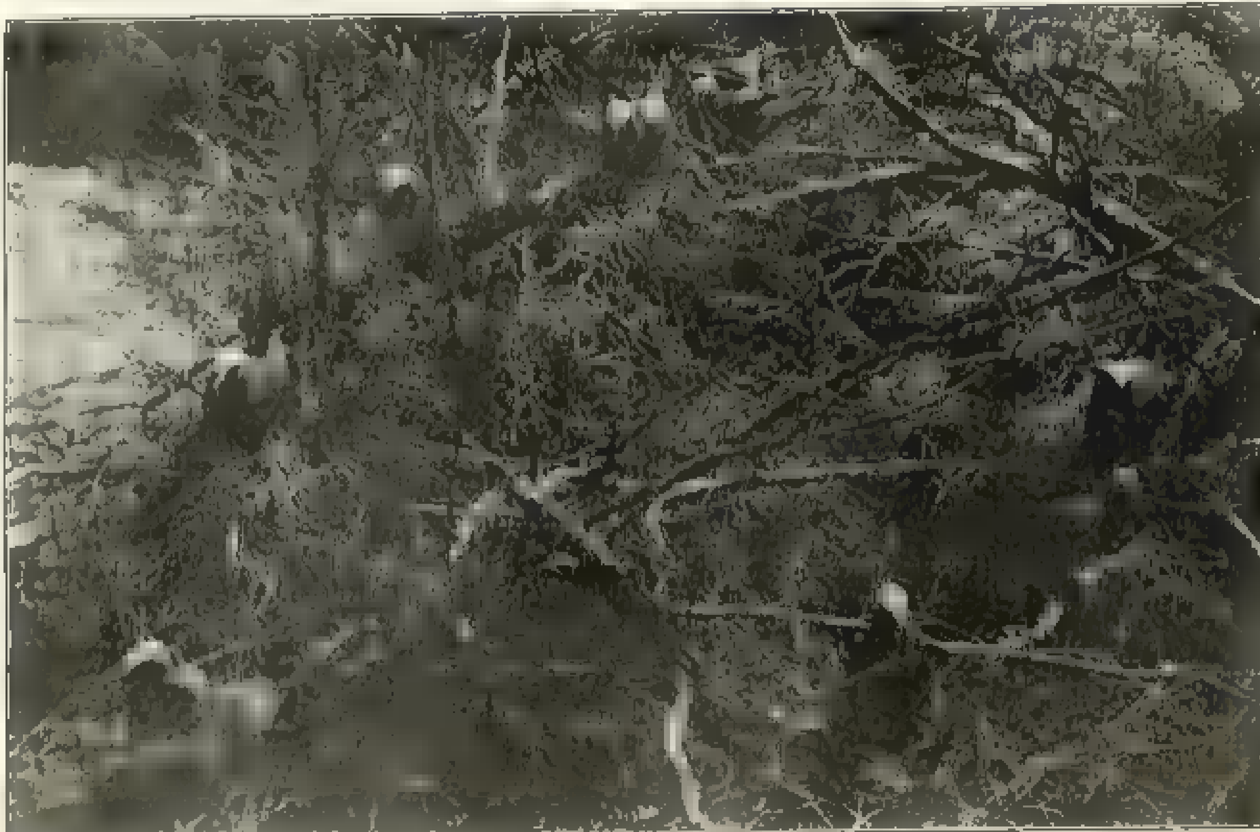
A. Bird old enough to try its wings. B. Bird just prior to beginning to fly.

A

B

A. GROUP OF ADULT SOOTY AND NODDY TERNS SUNNING THEMSELVES ON THE BEACH. B. OLD AND YOUNG OF BOTH THE SOOTY AND NODDY TERN ENJOYING A SUN BATH ON THE GLARING, HOT, WHITE SAND.

INSTANTANEOUS PICTURES SHOWING POSES ASSUMED BY SOOTY TERNS ON WING.



NODDY TERNS ON BIRD KEY, SHOWING HOW CLOSELY THE BAY CEDARS ARE CROWDED WITH THEIR NESTS.

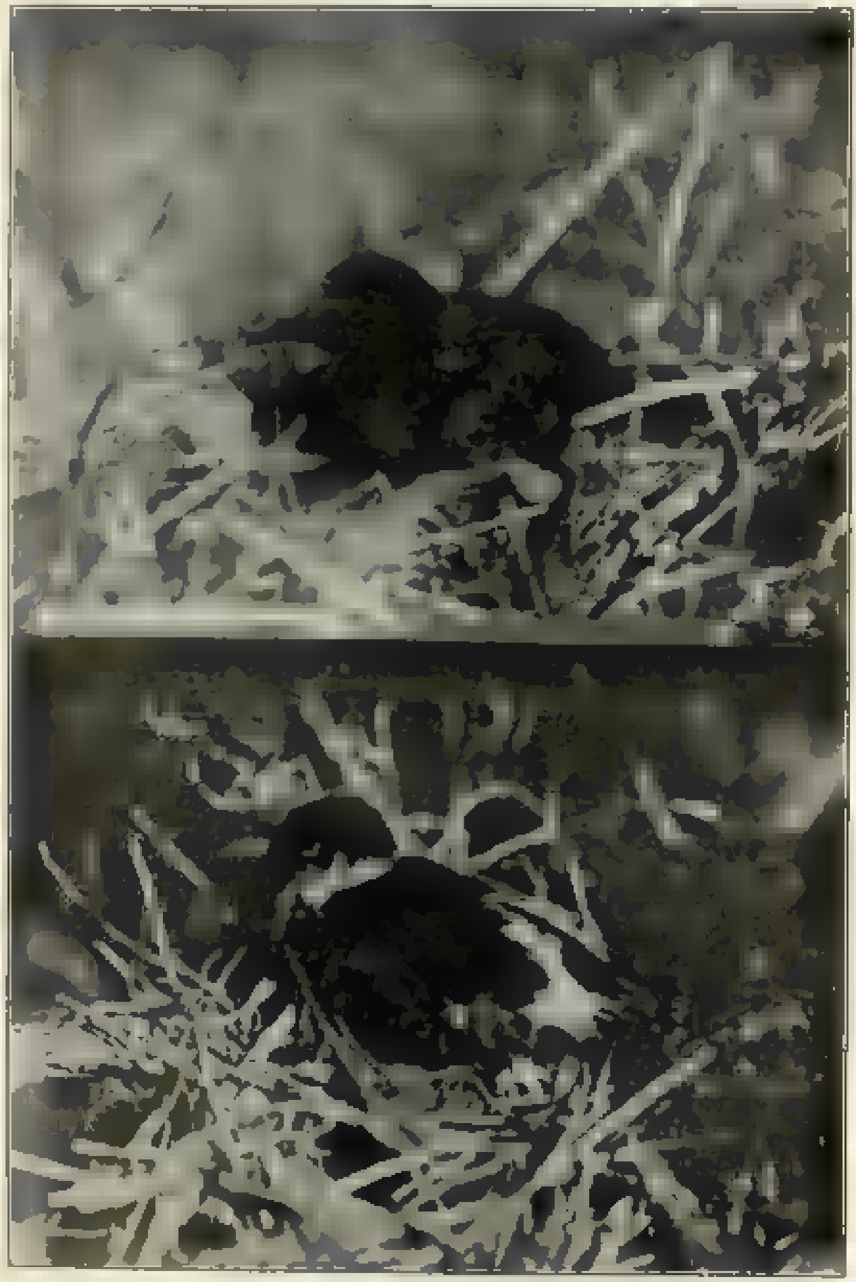
GROUP OF NODDY TERNS IN ONE OF THE TALL BAY CEDARS.

NEAR VIEW OF TWO NODDIES ON THEIR NESTS.

NODDY TERNS ABOUT THEIR NESTS, SHOWING CHARACTERISTIC ATTITUDES.
THE YOUNG BIRD IN THE MIDDLE PICTURE IS ALMOST READY TO FLY.

EGGS OF THE NODDY TERN SHOWING RANGE OF VARIATION IN MARKINGS.

Natural size.



A. YOUNG NODDY, PROBABLY A WEEK OLD; B. BIRD APPROXIMATELY 18 DAYS OLD.

Note development that has taken place in the interim.

A

B

A. NODDY ABOUT 22 DAYS OLD; B. NODDY ABOUT 28 DAYS OLD.

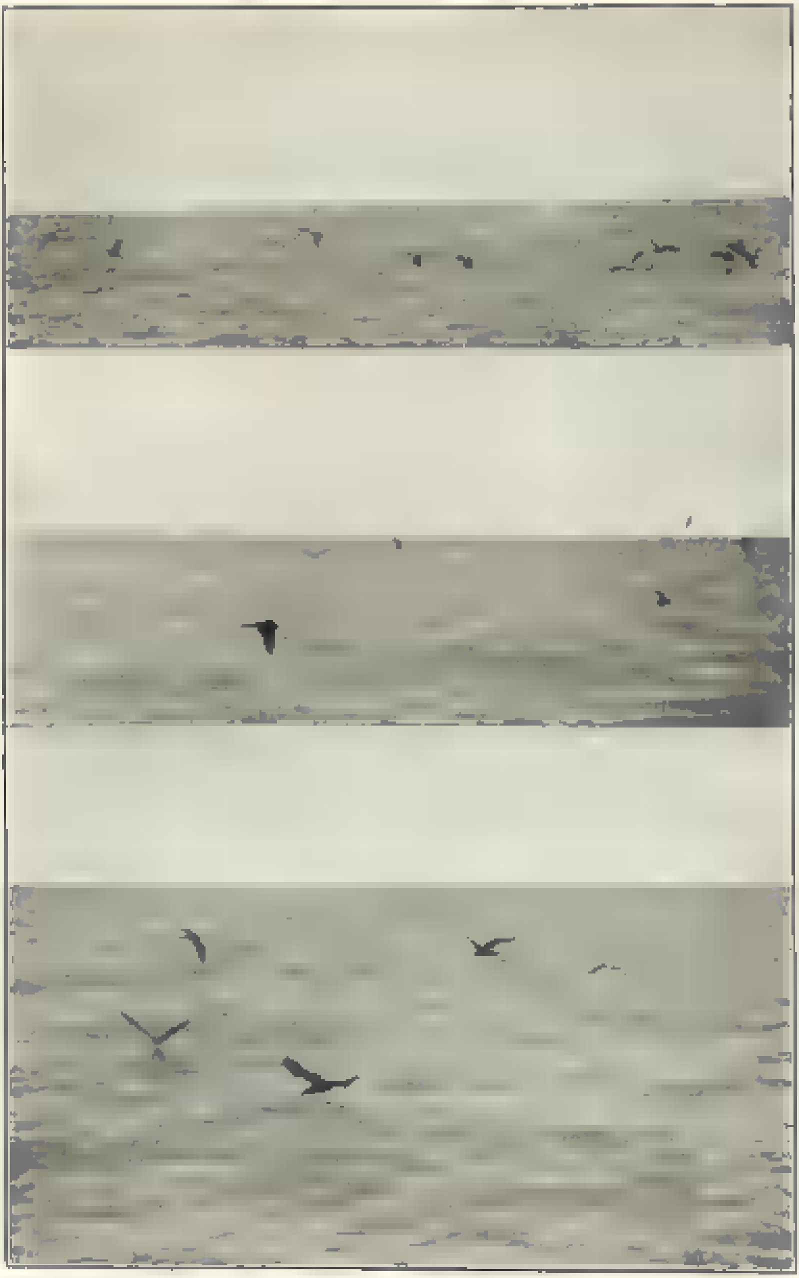
Note progress made in growth and feathering.

A

B

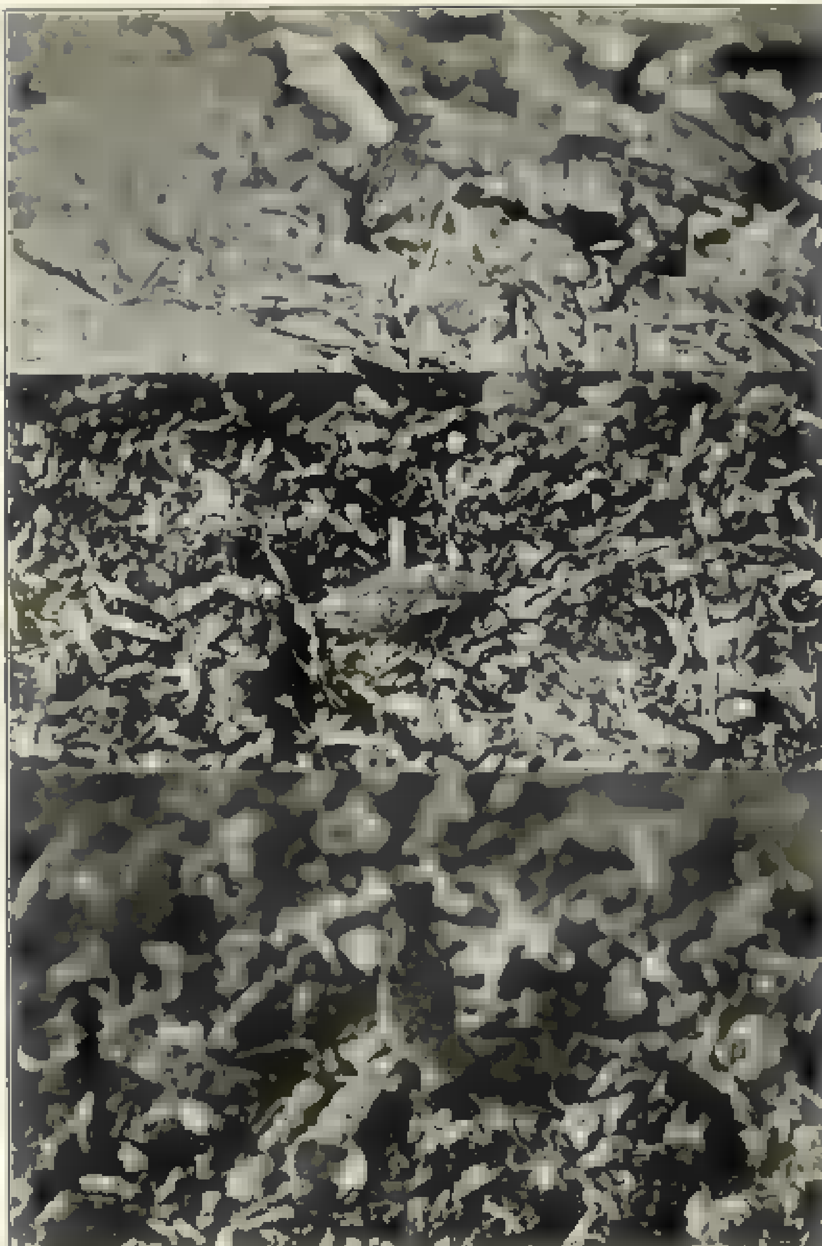
A. NODDY TERN ABOUT 40 DAYS OLD; B. ADULT BIRD.

Note difference between fledged bird and parent at the time the young begin to fly.

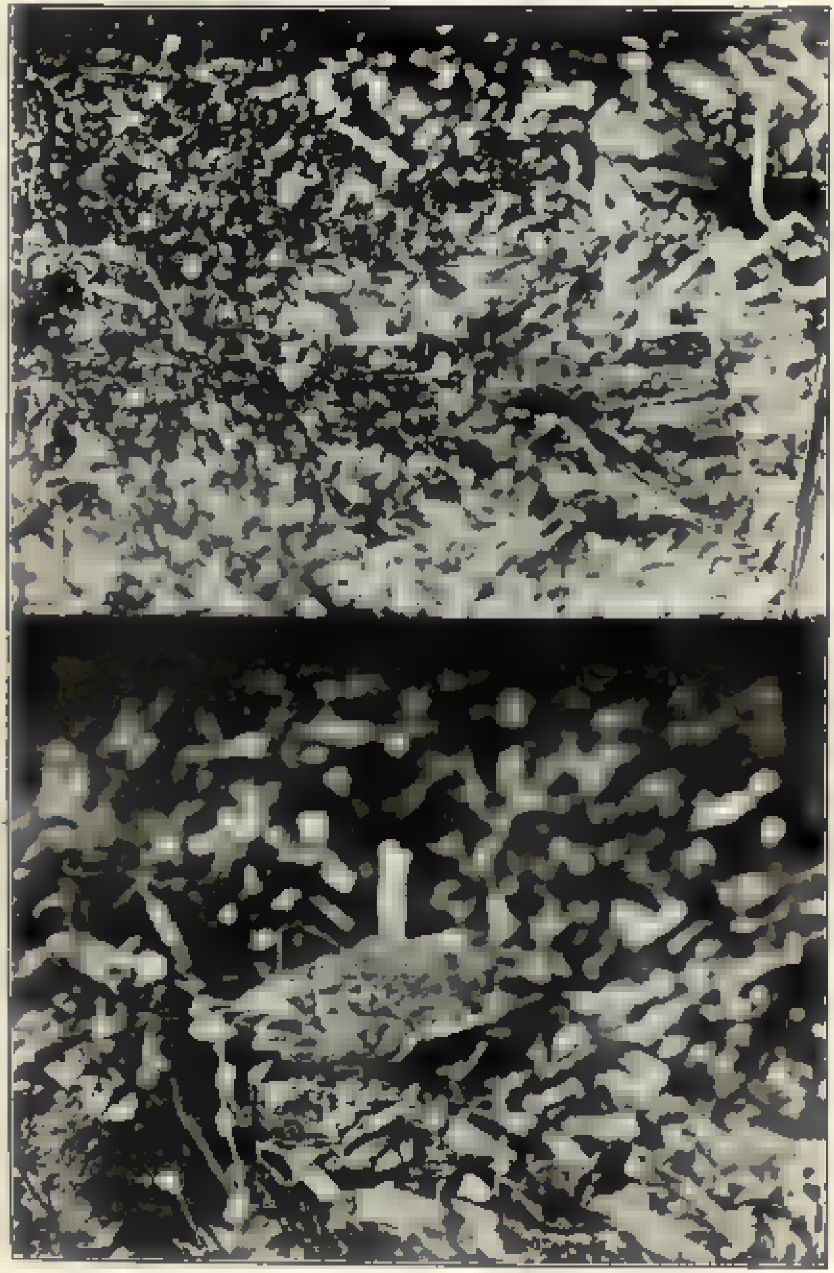


GROUP OF NODDY TERNS FISHING; FOLLOWING A SCHOOL OF JUMPING MINNOWS.

A LEAST TERN, HER NEST AND EGGS, SOUTH END OF LOGGERHEAD KEY, 1916.



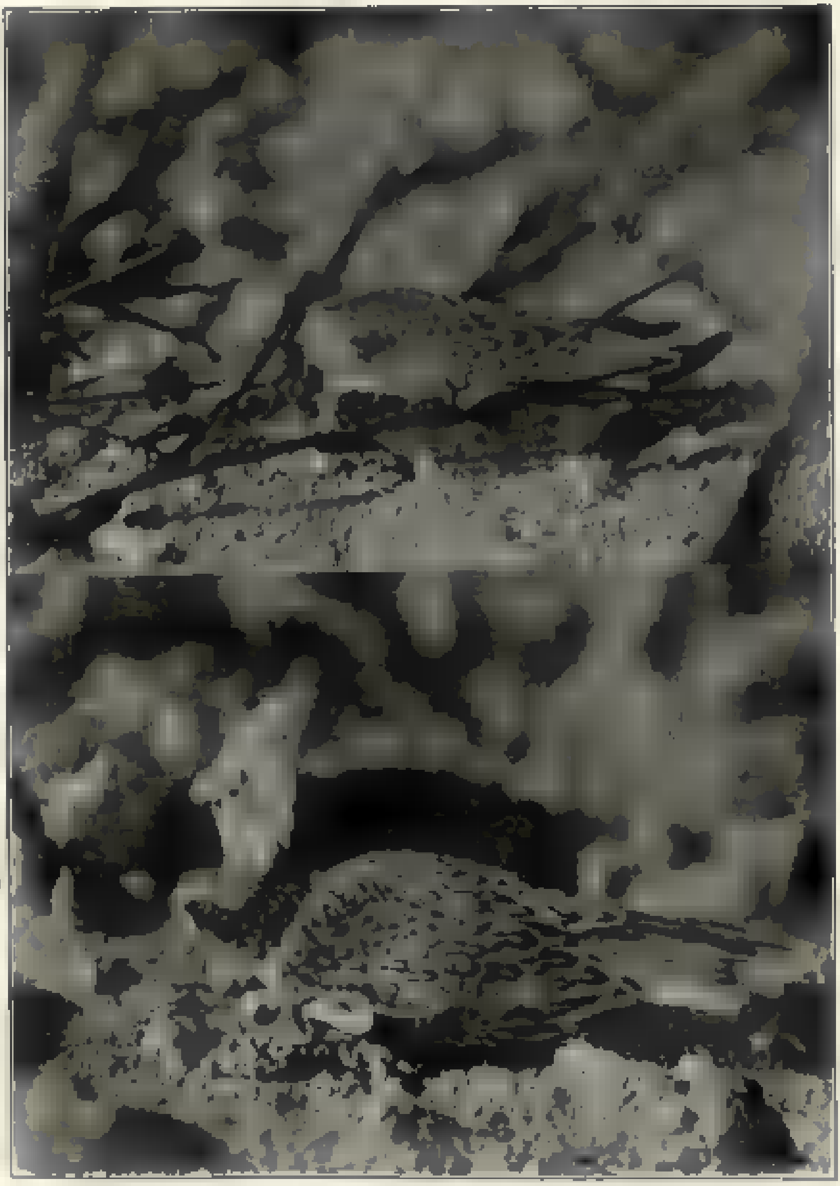
THREE YOUNG LEAST TERNS FROM COLONY ON SOUTH END OF LONG KEY, SHOWING DEVELOPMENTAL STAGES AND PROTECTIVE COLORATION.



TWO VIEWS OF YOUNG LEAST TERNS ILLUSTRATING PROTECTIVE COLORATION.

In the upper picture the bird is flattened against flotsam of the high tide line. The eye, a little to the left of the median line, will give a clue to the rest of the body.

A



B

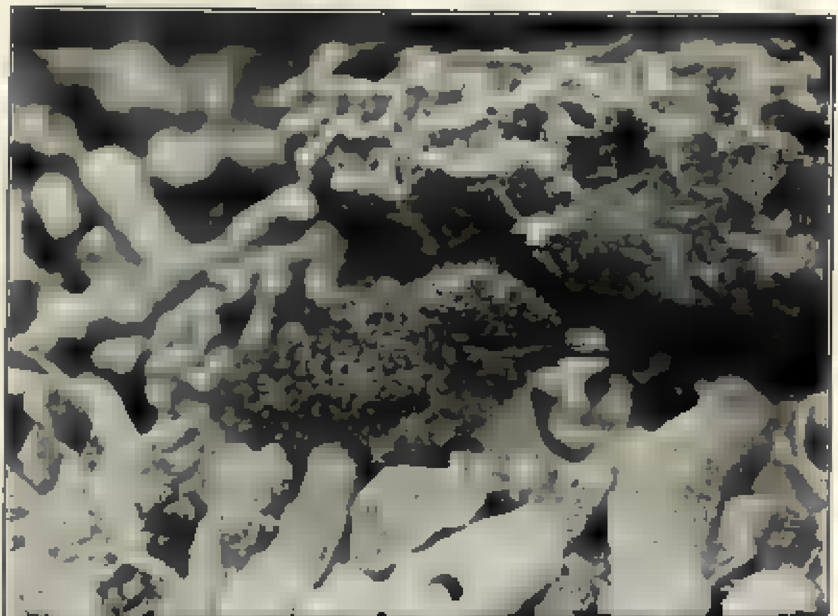
YOUNG LEAST TERNS.

A, Able to fly for a short distance; B, with wing clipped off by ghost crab.

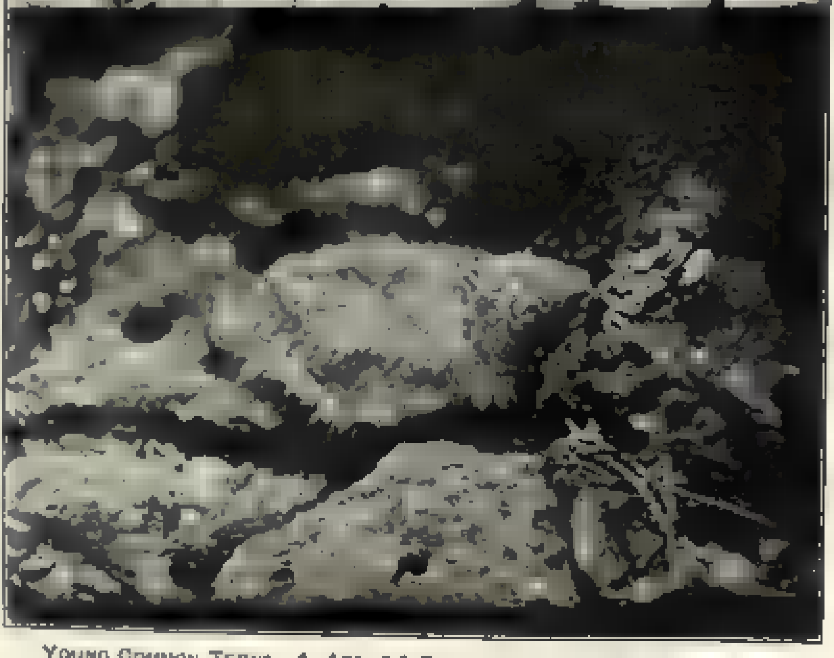
GHOST CRAB (OCYPODE ALBICANS BOSC). ONE OF THE DESTRUCTIVE AGENCIES ON THE TERN ROOKERIES.

BREEDING GROUPS OF THE COMMON TERN ON NORTH END OF LONG KEY: FLYING BIRDS ALSO MEMBERS OF THIS COLONY.

A

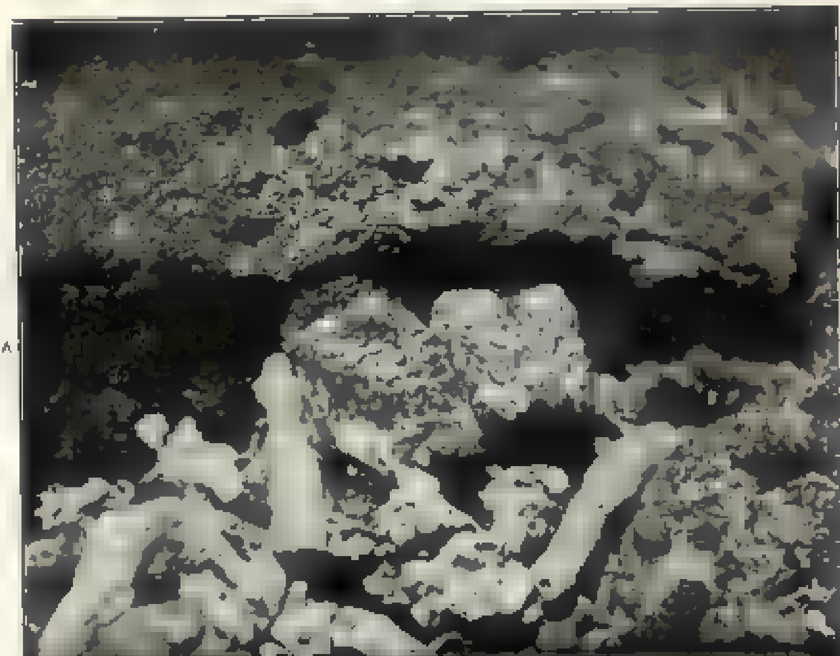


B

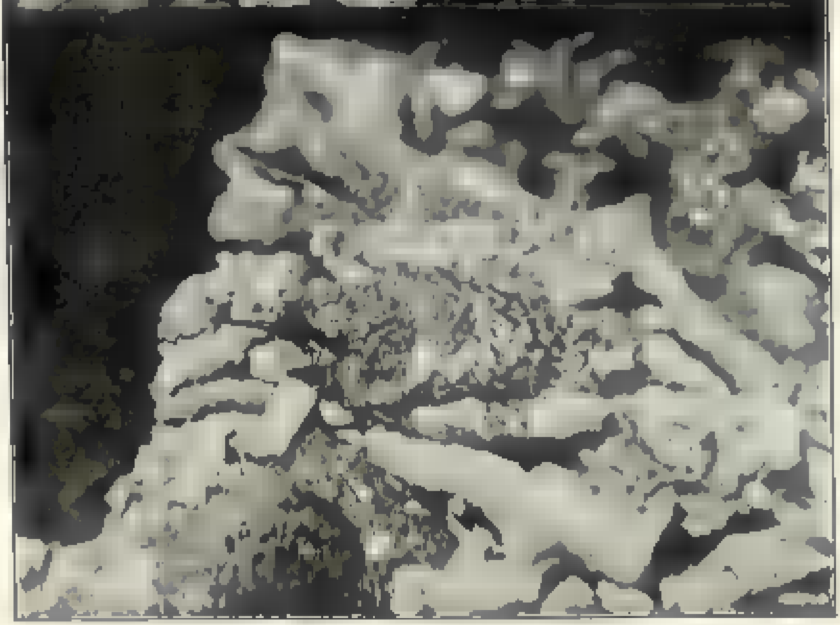


YOUNG COMMON TERNS. A, ABOUT 5 DAYS OLD; B, ABOUT 10 DAYS OLD.

A



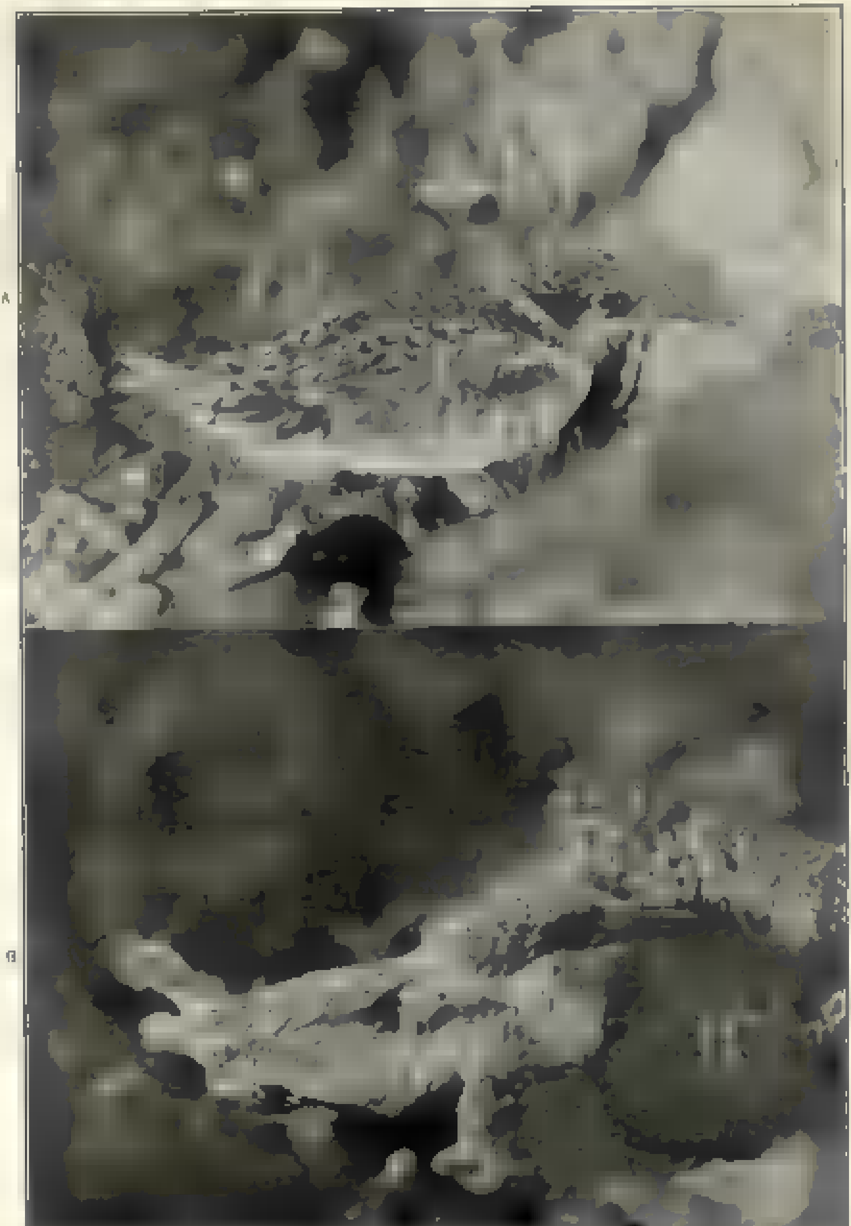
B



A. TWO YOUNG COMMON TERNS HIDING UNDER A DEAD CORAL BLOCK. B. THE SAME BIRDS WITH THE BLOCK REMOVED.

They are probably 4 and 12 days old, respectively.

YOUNG COMMON TERNS. A, ABOUT 2 WEEKS OLD; B, ABOUT 3 WEEKS OLD.



YOUNG COMMON TERNS. A, ABOUT [illegible] DAYS OLD; B, ALMOST READY TO FLY.

A. YOUNG COMMON TERNS SWIMMING OFF SHORE. B. YOUNG BIRD SWIMMING AWAY FROM SHORE.

MAN-O'-WAR BIRDS HUNTING IN KEY WEST HARBOR.

INSTANTANEOUS PHOTOGRAPHS SHOWING CHARACTERISTIC POSES OF THE MAN-O'-WAR BIRD ON WING, KEY WEST HARBOR.

MAN-O'-WAR BIRDS FISHING IN KEY WEST HARBOR.

SHORE LINE OF BIRD KEY, SHOWING GREAT NUMBER OF MAN-O'-WAR BIRDS.

A. PAIR OF LAUGHING GULLS ON THE NORTHEAST END OF LONG KEY. B. ROYAL TERNS SUNNING ON THE SANDSPIT, NORTH END OF LOGGERHEAD KEY.

BOOBYS PHOTOGRAPHED OFF BIRD KEY, TORTUGAS.

CATALEPSY IN PHASMIDAE.*

By P. Schmidt.

In the spring of 1912 the author obtained eggs of *Carausius* (*Dixippus*) *morosus* Br. v. W. which was imported from abroad and bred by amateurs in Petrograd nurseries. After hatching, he fed the growing material mainly on parsley. During the rearing he has made some observations and experiments which led him to conclude that these insects are subject to catalepsy.

Never very active, the young of *Carausius* are the most mobile. The adults, on the other hand, spend nine-tenths of their lives in a state of perfect stillness, as if transfixed. When at rest the four hind legs are extended, while the front legs are extended forward where their tarsi meet the ends of the antennae, which are also extended forward. The abdomen is also perfectly straight, the end alone being occasionally raised upward. This is the pose the adult insect maintains for hours, frequently a whole day without stirring leg or antenna. Only after long intervals of such quiescence, particularly at night, do some of them stir in search of food.

The transition from the state of rest into activity is accompanied by very rapid lateral swinging on its legs. Its active existence is always preceded by such vibration. This swinging frequently precedes also the transition into the resting state. The swinging, he believes, is for the purpose of starting circulation in its limbs which "go to sleep" during the extended quiescence.

A very few experiments sufficed to convince the author that the state of rest in *Carausius* is a state of catalepsy. Following are some of the observations the author records.

By carefully placing a forceps under the head of a resting specimen and raising it so that the portion composed of the head, pro and mesothorax forms an angle of 40° to 45° with the metathorax and then removing the forceps the insect remains in this position for hours. By aid of the forceps the folded front legs may be pried apart and placed at any angle to the body. *Carausius* retains this *Mantis*-like pose of prayer for hours. A specimen resting on the side of the jar may be flung to the bottom without provoking a change of the posture of rest. However, on falling, it often assumes another pose;

* Abstract from Rev. Russ. d'Ent., Vol. 15, No. 1, pp. 44–49 (1915).

it extends the anterior forelegs straight forward and the hind legs backward, all clinging close to the body, except the tibiæ of the last, which are set at a slight angle. This position represents a state of most perfect catalepsy and at the same time of perfect mimicry, because the insects retain it longest and in it most resemble inanimate objects, like sticks.

The insect thus lying still can be raised onto its legs without disturbing the cataleptic state. To do this one need but carefully bend its legs by means of forceps and they will retain the position given them; then it must be turned over and placed on its legs. During this operation some reflex stirring is observed occasionally, but it afterwards remains rigid in the given pose.

Standing on its legs the insect may be given any desired pose, not excepting most unnatural and difficult ones. It may thus be made to stand on three legs, by raising one of the middle ones. It may be made to stand on the four front legs and hold the hind ones raised. He sometimes succeeded in making it stand on three legs on one side, the end of the abdomen serving as support for the other side. The antennæ, too, may be extended forward, put back or placed at right angles to the body—and they will retain the position given them. Finally, the abdomen may, for instance, have its end bent upward almost to the vertical, a position never assumed by the adult insect.

Under a highly cataleptic state the insects can be stood on their heads, supported by the first two pairs of legs, or even the first alone, and the antennæ pointing the other way. One insect remained in this position for 4½ hours.

These simple experiments show that the phasmid's state of rest is different from the usual state of rest of animals. It differs radically from its state of activity which should be the normal but which in fact is more rare and of shorter duration. The resting insect passes into the active state after strong provocation as, for instance, when the end of its abdomen is pinched with the forceps or struck with it, etc. Sometimes the insect wakes also when an antenna or leg is pinched or it is simply breathed on, when it jumps up, takes several swings and runs. But sometimes it stirs, makes reflex motions, and returns to quiescence.

When awake *Carausius* reacts to all strong stimuli with energetic running. Thrown on its back, it immediately turns over and jumps to its long legs. Caught by the tail it strains with all six legs to extricate itself and run forward; caught by the antennæ it pulls backward. Any of its appendages raised are forthwith lowered and running away is induced. Thus no trace is left of the plasticity of the appendages observed in the resting insect. It reacts like a normal living animal.

But while these superficial observations show a strong similarity between the quiescent state of *Carausius* with the symptoms of *catalepsy* in man and higher vertebrates, greater study of details proves complete identity between the two categories of phenomena.

Closer examination shows first that the muscles of the resting insect are shortened and taut; femora and tibiæ, for instance, are at a certain angle to each other, to change which force must be applied, when again a definite angle is formed which is retained for a long time. This changing of angles, however, must not exceed the limits of the elasticity of muscles and ligaments. But the muscles are not as set as they are in tetanus. The muscles are plastic and yielding.

These properties of the muscles exactly characterize the cataleptic state of man and vertebrates (hare, hen, and frog). The eminent French physiologist, Ch. Richet, thus describes the cataleptic state of the muscle: "A muscle in catalepsy is slightly elastic, so that little strain takes it out of the original position; at the same time it is not quite elastic enough so that, taken out of the original position, it does not return to it and retains the new position indefinitely. Just as a piece of wax or butter retains impressions made in it, so the cataleptic muscle is changed by the mechanical influences to which it is subjected." A contracted muscle differs from the cataleptic in that the latter "is incomplete contraction. A tetanic muscle is very similar to a cataleptic. In both, voluntary shortening of the muscle is impossible, and of its own accord the muscle does not weaken; the difference is only that in catalepsy the shortening of the muscle is moderate and can be overcome by slight mechanical force, while in tetanus no force can overcome it." Thus the difference between contraction and catalepsy is quantitative only, *catalepsy is incomplete contraction.*

As a further characterization of catalepsy Richet gives "absence of fatigue: the contraction of the muscles, however taut and protracted, produces no sensations of fatigue, so that a muscle contracted remains so for many hours, days, and months even, producing no exhaustion or fatigue in the subject." This is true of the phasmids. It can not be said they do not *feel* tired, but this is established by the fact that they retain most difficult poses during long stretches of time. They also are as active at the end of a cataleptic fit as before it. Catalepsy is also characterized by the absence of feeling—"anesthesia"—the subject may be pricked, cut, scorched without reacting. Experiment proves this also true of cataleptic phasmids.

The author snipped one-quarter of the antenna of a resting phasmid. Sometimes there is slight shiver, due to shock, probably, but otherwise the insect remains motionless without even changing pose. Several minutes later another one-fourth antenna was cut: result

the same. Little by little he cut off the antennæ and began to cut off pieces of the forelegs; the insect is bleeding, but remains unmoved. He even cut off bits of the abdomen and still it remained unmoved. But let it be pinched on the cut end of the abdomen, i. e., given protracted excitement of the nervous system, it wakes from the trance and runs away.

No doubt, therefore, this is catalepsy. An experiment similar to hypnotism, may be performed with the insect by placing the ends of the extended legs and antennæ on one book, end of abdomen on another. Strips of paper may now be placed on the middle and the body thus weighted down, but the insect does not stir.

To ascertain the parts of the body with which catalepsy in *Carausius* is associated, what produces it and what is its biological significance and genesis, the author took a resting specimen and snipped it in two in front of the mesothoracic legs. The body remained standing on the four legs as if nothing had happened and the front part fell, also without changing pose. Several minutes later, however, the legs weakened apparently, and no longer supported the weight of the body, which sank to the surface of the table, but the legs retained their former position. But when the leg muscles were examined it was found their waxen flexibility had vanished. The body became very sensitive, reflex action is manifest. When a leg is touched it contracts and often the other legs also. Other tests showed that *no trace of catalepsy was left in this part of the body*. Some muscles, on the other hand, showed signs of a tetanus state, the seized legs breaking at the joints. He notes, by the way, the great vitality of this half of the insect; ligatured and protected from excessive desiccation it lived in one instance 12 days.

The head end has less vitality, lives only two or three days, but otherwise behaves as if it were attached to the body, the brittleness of the legs in the coxal joint being the only difference. *Catalepsy* is still there, if not so pronounced as normally. For hours the legs and antennæ remain extended cephalad, and can be placed in any desired position. By excitation it can be brought into activity.

The difference in behavior between the two halves of the body is explained by the fact that *catalepsy depends on the head ganglia* (the prothoracic, he found, does not count) and is induced by some special internal conditions surrounding muscles and nerves (like special composition of blood, excess of carbonic acid in it, etc.) and in all probability is *a special form of nerve excitation*. This specific excitation is produced by unknown processes in the central organ of the nervous system, and, permeating the entire nervous system, produces depression of reflex action, of sensation and a special state of muscle shortening bordering on contraction. The results of these

phenomena taken together, represent what we call catalepsy. With the severance of the connection between the nervous system and the head ganglia the possibility of this phenomena vanishes.

As to the causes producing this specific excitation of the nervous system the author can not say. All his attempts at producing it in active insects failed. They entered it more readily when left alone, showing the causes are internal and the author therefore calls it "autocatalepsy."

The author believes that the "death feigning" phenomenon is intimately associated with catalepsy and hopes soon to compare that of *Ranatra* with *Carausius*. He thinks it will be found that the immobility of caterpillars mimicking twigs and of *Mantis* in awaiting prey are similar phenomena. Finally, even hibernation may be related to it.

From the biological standpoint, the cataleptic quiescence of phasmids is only a specific adaptation of the muscular and nervous systems for the purpose of mimicking still portions of plants.

Compared with usual animal immobility, catalepsy is at an advantage: First, economy of energy, no fatigue developing; second, suppression of reflex action which might expose the insect.

This adaptation is most interesting and remarkable. It is not morphological, but physiological, and consists, moreover, in the development of a specific action of the nervous system which up to now was observed only in man-produced, artificial conditions—hypnotism of man and catalepsy of animals. Catalepsy in phasmids, the author believes, is the *first instance of normal, regular, internally produced catalepsy in the animal kingdom.*

AN ECONOMIC CONSIDERATION OF ORTHOPTERA DIRECTLY AFFECTING MAN.[1]

By A. N. Caudell,
Division of Insects, U. S. National Museum.

Orthoptera directly concerning man, either beneficially or injuriously, affect him either physically or psychically, that is his physical person, externally or internally, or his spiritual or emotional nature. Orthoptera may, to the uninitiated, appear scarcely worth mentioning as directly affecting man injuriously but literature contains a number of incidents of sufficient interest to merit brief reference. Forms injuriously affecting man's person externally is a subject dealing mostly with injuries inflicted by biting. In dealing with this and allied subjects it is not easy to separate popular superstitions from actualities and when the evidence rests upon the observations of laymen it is often more or less faulty. Actual incidents are evidently sometimes exaggerated by recognized observers and more popular and less scrupulous writers often go still further. Inexperienced or ignorant people misconstrue facts and thus our literature teems with questionable statements. This was especially true in times far past but continues true, unfortunately, to a considerable extent even yet.

A superstition long prevailed in Maryland that if a black beetle, that is a cockroach, enters your room, or flies against you, severe illness, or perhaps even death, follows.[2] As a recent example of evident error in observation I may mention a letter from a physician in New Mexico relating how a boy was bitten on the toe by a *Stenopelmatus* and, though the toe was immediately incised by a doctor, severe results followed, the boy being in a critical condition for some days and nearly losing his life. While it is very doubtful if the insect was the real cause of the boy's ailment, it is undoubtedly true that at least quite severe mechanical injury and pain may be caused by the bite of orthopterous insects. I have myself been bitten in the palm of the hand by a native *Orchelimum*, an insect scarcely exceeding an inch in length, so severely as to almost draw blood, and

[1] Reprinted from Proceedings of the Entomological Society of Washington, vol. 18, No. 2, pp. 84–92, 1916.

[2] Cowan's Curious Facts, p. 82 (1865).

similar bites on the finger or back of the hand by some of our larger and more powerful Orthoptera would easily pierce the skin. Davis states that *Bolocephalus* bites severely[1] and Bernard records natives sleeping in vineyards in France as being bitten by *Ephippigera*.[2] Brunner lost a piece of flesh, bitten out by the powerful jaws of Saga,[3] and Wellman writes that *Brachytrupes*, a large cricket, can draw blood with its strong jaws.[4] Cockroaches are known to bite off the eyelashes and nibble the toenails of children in South America,[5] and in addition they scratch the faces of men, bite the greasy fingers of sleeping children[6] and even eat the toenails of sailors.[7] And not only do roaches bite man but they annoy him in other ways. Thus, Reverend Laock, an early Swedish clergyman in Pennsylvania, had a roach enter his ear, causing intense pain until drowned out with water like a rat from its hole.[8] There are other similar incidents recorded and the name "earwig" was given the Forficulidae by reason of the widespread belief that they habitually enter the ears of man.

Orthoptera directly injuring man's person internally is a subject pertaining mostly to their causing disease and the dissemination of the same. This phase of orthopterous economy is closely connected with that dealing with external injuries by the entrance of the ear by roaches, etc., as mentioned above, and especially by injuries to the skin by secretions given off by certain species. Thus an African katydid exudes a clear yellowish fluid from pores in the side of the body near the junction of the thorax and abdomen which causes a quite severe eruption if it comes into direct contact with the skin. The natives appreciate and fear this property and its potency was verified experimentally by Dr. H. Stannus,[9] who thinks extensive ulceration of various parts of the body may sometimes result from this cause when proper medical advice is lacking. Certain earwigs are reported by Dr. Wellman to be considered poisonous by the natives of Angola, and Wellman himself thinks it possible that septic matter may be introduced by a "bite" from the powerful forceps of the forficulid in question.[10] Hasselt has written on an affection of the lips of persons to whose mouths roaches are attracted for food or drink.[11]

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[1] Journ. N. Y. Ent. Soc., vol. 20, p. 305 (1912).
[2] Tech. trait. Vigne (1914).
[3] Burr, Proc. S. Lond. Ent. Soc., 1899, p. (12) (1900).
[4] Ent. News, vol. 19, p. 29 (1908).
[5] H. H. Smith, in circular, 2 ser., No. 51, Div. Ent., U. S. Dept. Agric., p. 6 footnote (1907).
[6] Catesby, Nat. Hist. Carolina, vol. 2, p. 10 (1748).
[7] Gates, U. S. Naval Med. Bull., vol. 6, p. 212-214 (1912).
[8] Cowan's Curious Facts, p. 79 (1865).
[9] Bull. Ent. Research, Lond., vol. 2, p. 160 (1911).
[10] Ent. News, vol. 19, p. 32 (1908).
[11] Tijdschr. voor Ent., vol. 8, p. 98-99 (1865).

There are few Orthoptera recorded as the direct cause of disease in man. In 1872 there was published in Philadelphia an eight-paged pamphlet which reads like a production of pre-Plinyan days.[1] The writer contends that locusts and grasshoppers are the prime cause of the eruptive diseases of living things. He proves his assertions by biblical quotations and qualifies as a learned scientist by various interesting statements, such as that house flies originate from the intestinal worms of man. A more recent charge against Orthoptera as a direct cause of disease in man was brought to the attention of this society a year ago by Doctor Howard. This was a letter from a correspondent who drank a bottle of soda water and found a decayed roach in the bottom which he considered the cause of Bright's disease, a malady with which he was soon afterwards stricken. While the instances cited above involve elements liable to just criticism, there are others which are at least plausible and some doubtlessly well founded. Thus literature records several cases where grasshoppers, during great invasions, fell into the sea to be later cast ashore in such immense numbers that the air was polluted by the decaying mass, resulting in pestilential conditions costing the lives of many people. Also in times of grasshopper invasions the insects befoul the roofs of houses with their excrement and the rain water drained into cisterns from such roofs is defiled[2] and dysentery results from mechanical irritation by particles contained in such polluted water.[3]

However few or doubtful the records of Orthoptera directly causing disease in mankind, their instrumentality in the dissemination of disease organisms is a matter well worth consideration. Their importance in this respect is, of course, slight as compared with some other groups, especially the Diptera, and this phase of the subject is insignificant as compared with the general subject of medical entomology. But that certain Orthoptera, especially the Blattidae, may yet prove of real importance as disseminators of disease is not to be doubted. That they are well qualified for playing such parts is certain. Many published articles show cockroaches to be veritable hotbeds of various kinds of germs and that they fairly teem with bacterial organisms both inside and out.[4] Their eggs are covered with bacteria when deposited[5] and their feces show micrococci in abundance.[6] They may carry the hypopus stage of the cheese mite[7] and common cosmopoli-

[1] Riley, W. D., Locusts and Grasshoppers. The beginning and the end of the febrile or eruptive diseases of living things.

[2] Bull. Bur. Ent. U. S. Dept. Agric., No. 22, p. 108 (1900).

[3] Prout, Journ. Trop. Med. and Hygiene, p. 137–139 (1908).

[4] Herms and Nelson, Amer. Journ. Pub. Health, vol. 3, p. 929 (1913); Bartory and Clerc, C. R. Soc. Biol., vol. 64, p. 545 (1908), and Barber, Philippine Journ. Sci., vol. 7, p. 521–524 (1912).

[5] Petri, Mem. d R. Stazione di Patol. Vegetale, Rome (1909).

[6] Northrup, Tech. Bull. Mich. Exp. Stat., No. 18, p. 23 (1914).

[7] Ealand, Ins. and Man., p. 244 (1915).

tan species in Denmark have been proven to act as secondary host to a bacillus which produces cancer in rats.[1] Morrell concludes that the common croton bug, by contamination with its feces, is able to, and may possibly, play a small part in the dissemination of tuberculosis and in the transmission of pologenic organisms,[2] also that they are in all probabilities an active agent in the souring of milk kept in kitchens and that they are undoubtedly a very important factor in the distribution of molds to foods, etc., in cupboards and cellars. Gates states that roaches may spread typhoid on ships and carry in their intestines and on their feet the organisms of diphtheria, tonsilitis, and tuberculosis,[3] and some writers consider them fully as dangerous as house flies, as the virility of bacterial organisms is not diminished by passing through their alimentary tract.[4] A Danish professor claims that cancer is caused by drinking water in which cockroaches have oviposited[5] and roaches have been mentioned as possible transmitters of the tropical disease beri-beri.[6] Roaches have also been considered in connection with the carrying of the vibrios of Asiatic cholera,[7] and, in common with many other insects, they have been investigated as possible factors in the cause and spread of pellagra, but with negative results.[8]

There are few published references of Orthoptera, other than the roaches, as disease carriers, the only one now recalled being the spread of cholera for long distances by migratory locusts in Africa.[9] It is recorded that grasshoppers in times of invasions leave a cholera-like pestilence in their wake and they are also accused of carrying into uninfested regions the foot-and-mouth disease of cattle.[10]

Aside from physical effects, either external or internal as discussed above, man is injuriously affected directly by orthopterous insects scarcely at all. Aside from disagreeable odors of such species as cockroaches, etc., that offend his olfactory sense, his psychic nature is practically unaffected.

Orthoptera beneficially related to man directly may be divided, like those injuriously affecting him, into those affecting him physically and those influencing him psychically. The first group comprises species used in medicine and those eaten as food. The former, I

[1] Fibiger, Berliner Klin. Wochenschr., vol. 1, p. 289-298 (1913), Fibiger Hospitalstid., Copenhagen, vol. 57, p. 1049-1112 (1914), and Fibiger and Ditlevsen, Contr. biol. morph. Spiroptera (1914).

[2] British Med. Journ., p. 1631 (1911).

[3] U. S. Naval Med. Bull., vol. 6, p. 213 (1912).

[4] Longfellow, Amer. Journ. Pub. Health, vol. 3, p. 58-61 (1913).

[5] Nordlyset, New York, Feb. 20, p. 8 (1913).

[6] Van der Scheer, Journ. Trop. Med., vol. 3, p. 96-97 (1900); Manson, Tropical Diseases (4 ed.), p. 376 (1907).

[7] Barber, Philippine Journ. Sci., vol. 9, p. 1-4 (1914).

[8] Jennings, Amer. Journ. Med. Sci., vol. 146, p. 418 (1913).

[9] Riley, Ref. Handb. Med. Sci., vol. 5, p. 76 (1887).

[10] Kannemeyer, Trans. S. Afr. Philos. Soc., vol. 8, p. 84-86 (1895).

believe, is a matter based almost entirely on pristine beliefs and popular fallacies. A common European katydid is given the common name "wart biter" from the belief prevalent in Sweden that its bite removes warts.[1] Burr remarks that it is possible that the wound caused by the insect, together with the action of formic acid often exuded from the jaws of angry Orthoptera, and a goodly amount of faith on the part of the wart-stricken individual might, indeed, cause these mysterious growths to disappear. Ancient lore is replete with all kinds of cures attributed to various insects. The following recorded instances may be mentioned as pertaining to the Orthoptera. A leg of *Gryllus* boiled in water prevents retention of urine by man and animal.[2] Cockroaches bruised and mixed with sugar cure ulcers and cancers and kill worms in children; the ashes of burned roaches are an effective physic[3] and the inner viscera of roaches boiled in oil cure earache.[4] Cockroaches are made into tea and formed into pills for various ailments of man and powdered and extracted in alcohol they are a remedy for dropsy.[5] Oil of forficulids rubbed on the temples, wrists, and nostrils strengthens the nerves; ashes of house crickets cure weak sight and enlarged tonsils and triturated bodies of migratory locusts, with proof spirits, cure haemorrhoids and quench thirst.[6] There are many more such records of the remarkable medicinal properties of Orthoptera but no more need be repeated here.

As an article of food the Orthoptera are of real importance and the general use of insects as food for man is not only a matter of ancient history but of the present times as well. Doctor Howard has but recently urged experiments along this line,[7] and man of many climes annually consumes considerable quantities of insects and insect products. Were the present paper one dealing with insects in general this one topic of their use as food would be quite enough for one evening's discussion. Confined to the Orthoptera it is limited mostly to a consideration of the edibility of locusts, or grasshoppers. Other families of Orthoptera, however, enter somewhat into the diet of man and even the unsavory cockroach, when properly salted, is said to have an agreeable flavor for those fond of highly flavored dishes.[8] Personally, however, I have formed no liking for roaches as food, in spite of the fact that on a trip through the West I had them served to me alive in strawberries, a la carte with fried fish, and baked in biscuits.[9]

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[1] Proc. R. Lond. Ent. Soc., 1909, p. (11) (1909).
[2] Sanchez, Datos para la Medica Mexicana (1893).
[3] Sloane, Hist. Jamaica, vol. 2, p. 204 (1707–25).
[4] Cowan's Curious Facts, p. 82 (1865).
[5] Bogomolow, St. Petersb. Med. Wochenschr. (1884).
[6] Ealand, Insects and Man, p. 217 (1915).
[7] Monthly Letter, Bur. Ent., U. S. Dept. Agric., No. 18, p. 1 (1915).
[8] Lugger, 5 Rept. Minn. Exp. Sta., p. 80 (1895).
[9] Ent. News, vol. 15, p. 63 (1904).

At least one genus of Phasmidæ serve as food for man, the natives of Woodlark Island eating a species of *Karabidion*.[1] Gryllidæ, too, are eaten, field crickets being an article of diet in Jamaica when that island was first discovered,[2] and the natives of Africa eat quantities of *Brachytrupes*, which they dig from their burrows and prepare for the pot by removing the legs and wings.[3] The Orthoptera most extensively used as food are, as stated above, locusts, or grasshoppers. There is no doubt but that wholesome and palatable dishes may be prepared from the bodies of these insects and a somewhat extensive use is now made of them for this purpose by the natives of many regions. Ansorge says that John the Baptist needs no pity by reason of his entomological diet as he should tire of honey sooner than of locusts.[4] That the flavor of well-cooked locusts is not distasteful is vouched for by no less an authority than Dr. C. V. Riley. A somewhat extensive experiment was seriously carried out by Doctor Riley and others and the results summed up in his candid statement that, from personal experience, he considered our common locust more palatable when cooked than some animals commonly served on our tables.[5] In this experiment, which was given considerable newspaper notoriety at the time, locusts were prepared in various ways, all proving satisfactory. Ancient and recent literature is rich in reference to this subject and an interesting compilation of older accounts may be found in Cowan's Curious Facts, pages 120–131. I wish here to refer to but one of these ancient items, a poetic inventory of the larder of a poor Athenian family. The writer, Alexis, says:

> For our best and daintiest cheer,
> Through the bright half of the year,
> Is but acorns, onions, peas,
> Ochros, lupines, radishes,
> Vetches, wild pears nine or ten,
> With a locust now and then.

Under the title "Why not eat insects?" Vincent M. Holt has published an undated booklet of 99 pages treating of insects as food, and, while the menus suggested seem ludicrous, he is evidently sincere in his arguments. Recipes are given for the preparation of locusts, and the writer attests their palatability from personal experience and the testimony of others. I quote a menu from this work as a matter of interest, though locusts do not happen to be included in it:

[1] Montrouzier, Faune Woodlark, p. 62 (1855).
[2] Sloane, Hist. of Jamaica, vol. 2, p. 204 (1707–25).
[3] Wellman, Ent. News, vol. 19, p. 29 (1908).
[4] From Under the African Sun (1909).
[5] Proc. Amer. Assoc. Adv. Sci., p. 208–214 (1878).

Snail soup.
Fried soles, with wood louse sauce.
Curried cockchafers.
Fricassé of chicken with chrysalids.
Boiled leg of mutton with wireworm sauce.
Ducklings with green peas.
Cauliflower garnished with caterpillars.
Moths on toast.

The above menu, of course, sounds absurd, but is a raw oyster more attractive, gastronomically, than a well prepared locust? I say "well prepared locust," for nothing favorable can be said of illy prepared concoctions such as an unauthenticated account credits certain Indians with using, that is, fatty juices dipped from decayed masses of locusts and eaten as a salad. There is a justified vagueness as to the details of this practice but such salads need not be compared with the undoubtedly tasty and nutritious preparations civilized man might enjoy could he only overcome prejudices and eat insects. Chemical analysis shows locusts to possess a high nutritive value,[1] we have divine permission from the Bible to use them as food,[2] and they are admittedly tasty morsels, therefore why, indeed, not eat them?

My final topic, Orthoptera directly affecting man's psychic nature beneficially, is one of some importance. Man's aesthetic nature is appealed to by the beauty of many forms, his music-loving soul is soothed by their song and his sporting proclivities are gratified by contests of strength and valor between pugnacious males of certain species.

As objects of beauty a considerable number of Orthoptera are rivaled only by the most brilliantly colored butterflies. For example, certain giant lobe-crested grasshoppers of South America have the under wings brilliant with various hued tints, so blended as to incite the admiration of the most stolid observer. Certain mantids of the Old World are so constructed in form and color as to resemble brightly colored orchids. There are also many Orthoptera of more somber hues which are objects of admiration by reason of their wonderful forms, some exhibiting a marvellous array of spines and flanges, and others are so constructed as to perfectly mimic in form or color certain objects, as bark, twigs, etc. Our common walking-stick insect resembles, when at rest, the twigs among which it lives so perfectly as to merit our appreciation. Still other Orthoptera, which are neither brilliant in color nor striking in structure, are objects of interest by reason of their gracefulness of form or agility of motion.

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[1] Howard, 1st Rept. Locust Bur., p. 59–60 (1907).
[2] Leviticus, ch. 11, par. 22.

The songs of insects have been enjoyed and applauded by man since the dawn of history and among our musical insects the Orthoptera are dominant. So musical are the notes of some of our orthopterous songsters that it is difficult to express their melody. The rhythmic beat of the tree cricket has been termed by Burroughs as a "slumberous breathing," while Hawthorne describes it as "audible stillness" and declares that "if moonlight could be heard it would sound like that."[1]

Various efforts have been made to set to music the notes of Orthoptera. Scudder made the attempt with the songs of a number of species[2] and Regen has attempted it with the notes of *Thamnotrizon*.[3]

A species of large katydid is kept captive by natives in South America for the sake of its song[4] and the natives of Africa are lulled to sleep by the song of caged crickets.[5] Some species, indeed, are objects of barter in some regions. Thus gryllids are sold in little cages in the streets of Florence on Ascension day as songsters[6] and caged crickets are sold in Portugal for their song and for the good luck which they are supposed to bring their owner.[7]

Considerable use is made of Orthoptera in sport, especially in China and Japan. The Chinese are much given to gambling and are said to win and lose fortunes on cricket fights as American sportsmen win or lose at horse races. In China the fighting crickets are trained and cared for as carefully as if they were blooded horses. They are given a fixed diet, partly of honey and boiled chestnuts, and if one falls ill it is fed on mosquitoes. A good cricket fight will last half an hour and, to win, one of the combatants must slay his adversary or throw him bodily over the 6-inch wall inclosing the arena. These fighting crickets, which are all males, are bought and sold like horses, one with a good record bringing $5 or $10, while a champion often sells for as much as $50.

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[1] McNeill, Ent. Amer., vol. 6, p. 103 (1889).

[2] Hitchcock's Rept. Geol. New Hampshire, vol. 1, p. 362–390 (1874); 23rd Ann. Rept. Ent. Soc. Ontario, 1892, p. 62–78 (1893).

[3] Sitz. ber. Akad. Wiss. Wien, Math.-Nat. Klasse, vol. 97, p. 487–488 (1908)

[4] Bates, Journ. Ent., vol. 1, p. 474–477 (1863).

[5] Moufet, Ins. Theatr., p. 180 (1634).

[6] Burr, Proc. S. Lond. Ent. Soc., 1899, p. 12–18 (1900).

[7] Bather, Bull. Brooklyn Ent. Soc., vol. 8, p. 56 (1913).

AN OUTLINE OF THE RELATIONS OF ANIMALS TO THEIR INLAND ENVIRONMENTS.[1]

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THE DYNAMIC RELATIONS OF ANIMALS.

1. INTRODUCTORY NOTE.

As creatures of habit, the attitude of mind with which we approach a scientific problem has much influence upon what we see in it or get from it. Although the essence of life is activity—the response of the changing organism to its changing environment—yet this dynamic conception of animal relations, *and all that it implies*, has not become as prevalent a mental habit among biologists as one might expect. While some naturalists view the animal from a more or less dynamic standpoint, they do not include a similar conception of the relation of an animal to its environment. Still others view the environment more or less dynamically but do not extend this conception to the animal, and thus both of these conceptions lack completeness and are not thoroughgoing and consistent. The study of activities, or in other words the study of processes, has made great progress in the allied sciences, much to their advantage, and undoubtedly the prevalence of similar conceptions will lead to similar advances in biology.

In the present brief paper I have attempted to discuss only certain phases of the problem with the idea of emphasizing the general principles involved, and in the hope that it may aid in making these conceptions of more practical value in investigation, and also facilitate an understanding of the discussion contained in a report on the invertebrates of the Charleston (Illinois) region, to appear in a subsequent paper of this volume of the Laboratory Bulletin.[2]

2. THE RELATIONS OF ANIMALS TO THEIR ENVIRONMENT.

The study of animal ecology may be taken up from many sides and in many ways. One of the most interesting and fundamental of these

[1] Reprinted, with the addition of the footnotes, from the Bulletin of the Illinois State Laboratory of Natural History, vol. 11, pp. 1-32, 1915.

[2] An Ecological Study of Prairie and Forest Invertebrates. L. c., pp. 33-280, 1915.

is that which considers the *dependence* of the animal upon its environment, and at the same time orients it in the gamut of energies and substances. Many phases of this discussion, though elementary and for this reason easily overlooked, are yet of fundamental importance. Every boy who has kept pets in confinement, and who has had the responsibility of caring for them and every one who has cared for domestic animals, knows what constant attention must be given to keep them supplied with food, water, shelter, and other "necessities of life." And who can overlook the fact that it requires attention to maintain his own physical health? In the laboratory this dependence upon the environment is readily tested experimentally by any method of isolation which will prevent an animal from securing any "vital necessity" as air—when sealed in a vessel; or food—when locked up without it; or a favorable temperature. No animal can survive such isolation from its normal environment. Every student of animals in nature must also realize that similar supplies and conditions determine and control the existence and welfare of all *wild* animals. The animal is not self-sustaining, but requires a constant intake of energy and substance from its environment. Chemical methods will readily show the source from which the materials composing the animal body have been derived. The ash came from the soil or rock, and shows the animal's dependence upon the solid earth: the liquids came from the water of the earth and constitute from 50 to 95 per cent of the bulk of the animal's body, showing that a relatively large quantity of this substance is essential to all living animals; the abundant gaseous element was derived from the atmosphere, to which it will again return. The substance composing the animal body is thus derived mainly from the water and the air rather than from the relatively inert and stable earth. It will be profitable for us to imagine these proportions so changed that the solids instead of the relatively mobile liquids and gases form the principal mass of the body, keeping in mind meanwhile the slow rate of chemical change in solids compared with the change in substance in a finely divided condition, such as liquids and gases. If the solids predominated, the rate of the chemical change, upon which the active life of animals depends, would be greatly retarded, and animals, including man, would be stolid beyond comprehension. Furthermore, we must not overlook the fact that animals are not maintained solely by substance, because substances are also carriers of energy, substance and energy never being separated. The living animal is not a *producer*—it can make neither substance nor energy—nor is it a kind of energy; it is solely a *transformer*, a chemical engine which changes the form of substance and chemical energy and produces new combinations from the old. The living plant transforms energy and inorganic substance, from the air, water, and earth, into complex chemical com-

pounds, and thus concentrates powerful chemical energy in such a form that the animal, by a further change, is able to set it free and to utilize it. Sugar, starch, and gluten are familiar examples of this "tablet" or "cartridge" form of chemical energy which animals explode or set free and then use in maintenance. During this transformation, in which chemical energy is set free, waste products—inert chemical substances—are formed which if not eliminated from the animal system will prevent its operation, just as ashes if not removed will check a furnace. Respiration aids in the removal of carbonic-acid gas—a waste product—from the body, but we often forget that the chemical energy derived from the oxygen is an important feature in respiration. By another process the liquid and the solid waste is removed. Thus gases, liquids, and solids are taken into the body and later returned to the environment in a different chemical condition, thus completing a cycle of transformation. That the animal body is so largely made up of solutions and gaseous substances is an important factor in its relatively unstable chemical condition, a condition of *unstable equilibrium*, which determines the active and dynamic character of the animal. Since, then, chemical activity is one of the essential characteristics of a living organism, its influence forms one of the main problems of the zoologist when studying the changes in animal activities, their orderly sequence, and the laws which govern them.

On account of the fact that the animal is a chemical engine, it is able to use chemical energy to the fullest extent. If we assume a hierarchy in the forms of energy, chemical energy seems to belong to the upper class; for though some forms of energy are not readily transformed into chemical energy, chemical energy can be transformed into *all others*. As a result the animal, being a chemical engine, has, as it were, an "inside track" to the main sources of energy, and thus by transformation is able to utilize chemical energy to form light, as in the firefly, or electricity, as in the electric eel; and other forms of energy useful to the animal are similarly derived. This study of the activities of living animals, as contrasted with the study of dead ones, is a phase of the general science of energetics, a science which furnishes the basis for the correlation of many diverse branches of knowledge.

The activities and transformations within the animal body show us very clearly how an animal is dependent upon environmental conditions. The animal transforms air, water, and rock, and all animal habitats and environments must contain these elements. In nature these are combined in a multitude of ways. The interrelations of these fundamental environmental units have been strikingly expressed by Powell (1895:22–23) as follows:

The envelopes of air, water, and rock are so distinct that they can be clearly distinguished; and yet, when they are carefully studied, it is discovered

that every one encroaches upon the territory of the others, not only by interaction but also by interpenetration. It has already been shown that the water penetrates deep into the rock. Every spring that falls from the hillside gives proof that the rocks above its level hold water, which they yield slowly as a perennial supply; and the innumerable hills of the continents and islands have their innumerable springs. Every well proves that there is water below; every artesian fountain shows the existence of underground waters; and every boring in the crust of the earth, and every excavation in underground mining, discovers the presence of water.

Wherever water flows, air flows with it, and all natural waters are permeated with air.

The aqueous envelope is everywhere permeated with rock, which it holds in solution or suspension, and there is no natural water absolutely pure. The sea is full of salt. Salt lakes are more than full of salt, and so they must throw it upon the bottom; and the waters hold lime and many other substances. Not a drop of pure water can be found in the sea; not a drop can be found in a lake; not a drop of pure water can be found in any river, creek, brook, or spring; and not a drop of pure water can be found underground; it is all mixed to some degree with rock.

All natural waters are aerated. No drop of water unmixed with rock and air can be found, except by the process of artificial purification.

But surely there is pure air? Nay, not so. There is no natural air unmixed with rock and water. All the air that circulates above the land and sea, within the ken of man, and all the air which circulates underground, is mixed with rock and water.

Pure air is invisible; it will not reflect light; it is transparent, but will not convey light. Light is conveyed through the atmosphere by ether, and is reflected and refracted by rock and water; and it seems to be largely affected in this manner by rock. If the ambient air of the earth were pure, there would be no color in the sky, no rainbow in the heavens, no gray, no purple, no crimson, no gold, in the clouds. All these are due largely to the dust in the air. The purple cloud is painted with dust, and the sapphire sky is adamant on wings.

Land plants live on underground waters; were there no subterranean circulation of water, there would be no land plants. Fishes live on underwater air; were there no circulation of subaqueous air, there would be no fishes in the sea. The clouds are formed by particles of dust in the air, which gather the vapor; were there no dust in the air, there would be no clouds; were there no clouds, there would be no rain.

Up to this point we have considered mainly the processes of maintenance of the animal body, but there are other processes as well which must be called to mind, such as growth, development, multiplication, and behavior. Physiologically considered, none of these activities are essentially different from the fundamental phases of metabolism and all are dependent upon it; they are special forms of the transformation of substances and energy within the animal. As the individual animal grows and develops in its life cycle, its metabolism, form, and behavior change in an orderly manner, and this transformation is in the main a continuous process like the other transformations of matter and energy. The changes which take place during ontogeny are often greater than the differences which

exist between very distantly related adults, and these differences result in very different rôles which the animal often plays in the economy of nature.

Comparable to the responses of the animal to its environment, and indeed essentially of the same kind, are the responses of any part of an animal to all its other parts, the entire organism, in this case, being considered as a unit. The environment of an internal parasite is formed by the body of its host, and in a similar sense the different parts of the body are parts of the environment of the other parts. The different parts of the animal body are what they are on account of three conditions. The first is determined by its relative position and responses as a member of a series of successive generations. In this way the hereditary potentialities are determined. Ecologically considered heredity may be regarded both as the response of individuals (unicellular) and germs to the conditions of life, and as the mutual responses of different germs to one another. The crossing and intermingling of germinal elements is as truly a response as are other forms of activity. Secondly, there is considerable evidence which indicates that *at some stage* in the development of an animal any part is potentially capable of developing into any other part. The character of development, then, is conditioned by the character of the cell-environment—its relative position, and all that implies with regard to environment. A fragment of a regenerating animal develops differently according to its position, and this is a response to its relative position in the cell community. Thirdly, the development of an animal is conditioned by its external environment. The external conditions influence animals by changing their internal activities. The internal changes modify the cell community and change development. In this manner every part of the animal is influenced by the conditions of its existence.

The processes of metabolism are continuous as long as life lasts. Thus, as an animal respires there is a gaseous exchange, from the earliest stages of its existence until its maturity and death. Eggs respire as surely as larvæ and adults, and the chemical, physical, and physiological changes within them vary with their growth and development. Some of these changes are primarily dependent on the orderly course of development during the life cycle, and are therefore irreversible processes, because no higher animal which is mature may reverse its development and become young again. At different stages of development different enzymes and harmones appear which modify the physiological conditions of growth, development, and behavior. Environmental changes, persistent and uniform, or periodic in character, tend to modify and alter these internal processes, and are an additional source of change, which is particularly shown in behavior.

It is interesting to observe in this connection that certain factors are important as they *hasten* or *retard* other processes. Thus enzymes hasten chemical changes which without them would take place at a very slow rate, and they set free much energy in a relatively short time. Temperature is another hastener of chemical reaction. Not only is it a condition which sets limitations on the chemical reaction in animals, but it also influences their optimum, and with increasing temperature chemical changes take place within the animal irrespective of the control of the animal, except in the warm-blooded animals, where a mechanism exists which regulates, within certain limits, temperature conditions.

5. OPTIMA AND LIMITING FACTORS.

We have seen that the animal is dependent upon its environment for both substance and energy. If, therefore, the environment does not contain, in available form, both substance and energy, animals will not be able to live in it permanently, although with energy stored in their bodies they may be able to make more or less prolonged and successful invasions into such an environment. The optimum is the most favorable condition for any function. We may consider optima corresponding to units of different rank; a single cell or tissue in action, an organ or system of organs, the animal as a whole, a taxonomic unit—and so on, to an animal community or association. There are, then, many kinds of optima, and the study of the conditions which produce them is a complex subject. The optima for different functions may differ much; for example, that for growth is often different from that for reproduction, and the optima may also change greatly with the development of the animal. Optima, therefore, are not fixed conditions, even though they do represent a condition of physiological *relative equilibrium*. The amount or intensity of substance and energy which produces an optimum is limited above by the maximum and below by the minimum. Thus departures from the optimum, toward an increase or a decrease, are departures *from* the most favorable conditions toward less favorable conditions, and hence toward limiting conditions. This form of expression is mainly that of the laboratory; it is desirable therefore, in addition, to express it in terms of the normal habitat. In nature we look upon the optimum as that complex of habitat factors which is the most favorable, and departure in any direction from this optimum intensity is in the direction of a less favorable degree of intensity or into unfavorable conditions. From this standpoint *any unfavorable condition is a limiting factor* and may retard, hasten, or prevent vital and ecological activities. Optima are thus almost ideal conditions, and are probably realized in nature only to a limited degree; in other words

only approximately. Here also, as in the laboratory, they represent a condition of *relative equilibrium.* The laws of the transformation and development of optima are of great ecological importance, as I pointed out several years ago (1904). In field study probably the most valuable criterion to be used in the recognition of ecological optima is the normal relative abundance and influence of animals in their breeding environment.

In the preceding discussion no special emphasis has been placed upon the time element, or the rate at which changes may take place. Natural environments are complexes, in the composition of which several factors are involved. This being true, it is desirable to recall the fact that the *rate of change* is determined by the pace of the slowest factor, or, as Blackman (1905 :289) has expressed it:

> When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the "slowest" factor.

This is a general law and applies to all changes, internal as well as environmental.

In closing this section, I wish to call attention to another conclusion of the English plant physiologists Blackman and Smith. They state (1911) that from experimental study of the assimilation of water plants, the conception of the optima is untenable, and that the phenomena are better explained as the result of "interacting limiting factors than by the conception of optima" (p. 412). This principle is formulated as follows (p. 397):

> When several factors are possibly controlling a function, a small increase or decrease of the factor that is limiting, and of that factor only, will bring about an alteration of the magnitude of the functional activity.

It will be of much importance to test the application of this idea to animal responses.[1]

4. DETERMINATION OF DYNAMIC STATUS.

In any study of the energetics of organisms it is desirable to have clearly in mind one of the fundamental conceptions of this science—the dynamic status. The law of conservation of energy teaches us that energy can not be destroyed; that it is transformed only, and thus undergoes a cycle of changes. The animal or an animal community, as a unit and as an agent or transformer, is constantly transforming energy, setting it free. In this sense it originates, but not at a uniform rate. At one time much energy may be transformed and at another very little. When a great amount of energy is being set free, when the animal or community is exerting much influence, we may look upon it as producing pressure or strain. A condition

[1] See also my paper, Migration as a Factor in Evolution: Its Ecological Dynamics. American Naturalist, vol. 52, pp. 465–490, 1918; vol. 53, pp. 55–78, 1919, for additional reasons for discarding the conception of optima.

of stress is not a permanent one, because the pressure tends to cause such change as will equalize or relieve this condition. This is considered as the process of adjustment to strain, and is called Bancroft's law (1911). An animal in an unfavorable condition is stimulated, its normal activities are interfered with, and a physiological condition of stress is produced which lasts until by repeated responses or "trials" the animal escapes stimulation or succumbs and a relative equilibrium is established. An area may become overpopulated and consequently there may be established a condition of stress, which results in an adjustment by a reduction (through many causes) in the excess of population and a restoration of the normal, or a condition of relative equilibrium. From these examples it may be seen that the *dynamic status* means the condition of a *unit* or system with regard to its *degree of relative equilibrium*. The cycle of change may be considered to begin at any point. I have taken as the initial stage of the cycle the condition of *stress* or *pressure*, and have indicated how this condition tends to change in response to pressure, bringing about the *process* of adjustment to strain, and leading to the *condition* of adjustment to strain, or that of relative equilibrium. The activity of the agent produces the condition of stress, the process of adjustment to the strain follows, and this leads to the product—the establishment of the condition of adjustment or of relative equilibrium.

These conceptions are very suggestive when applied to various phases of organic activity, and aid greatly in utilizing the dynamic conceptions which are in constant use in many of the physical sciences. But we can not assume that these ideas will take definite form unless the student makes some special effort to master the principles involved.[1]

6. ANIMAL RESPONSES.

The general character of the changes within the animal, which result in the transformations of energy and substance or the process of metabolism in its broadest sense, is the basis of all animal responses. It is well known that growth, development, and behavior are conditioned by certain metabolic processes, the rate of which are further conditioned by the presence of certain substances, as enzymes (from liver, etc.), and internal secretion (from thyroid, testes, adrenals, etc.). The influence of certain physiological conditions or processes is thus well known to affect the behavior of animals. The changes of instinct through the removal of the testes or ovaries, may be cited as examples of this influence. An animal whose metabolic processes

[1] See Adams's Migration, etc. (*loc. cit.*), for an amplification of dynamic principles, a discussion of the relation of Bancroft's law to the phase rule, and the biological significance of these ideas.

have reached a certain stage is said to be satiated; later it is in the condition of incipient hunger; and still later, in the physiological condition of intense hunger. These internal changes cause the animal to react very differently to any food which is in its immediate vicinity. These changes in physiological conditions are strictly comparable to the change which an animal passes through in its ontogeny; to the life cycle of an insect, for example, in which the physiological conditions and behavior of a caterpillar are very different from those of the pupa and of the adult or moth. One of the higher animals, a dog, for instance, will undergo internal changes which will completely alter its responses at the sight of an old rival or enemy. Such considerations as those just cited show clearly that extensive internal physiological changes take place in animals, and that while some of them are very gradual others are exceedingly rapid. These internal conditions or changes have been well characterized by Jennings (1906:289) as follows:

> The "physiological state" is evidently to be looked upon as a dynamic condition, not as a static one. It is a certain way in which bodily processes are taking place, and tends directly to the production of some change. In this respect the "law of dynamogenesis," propounded for ideas of movement in man, applies to it directly (Baldwin, 1897:167); ideas must indeed be considered so far as their objective accompaniments are concerned, as certain physiological states in higher organisms. The changes toward which the physiological state tends are of two kinds. First, the physiological state (like the idea) tends to produce movement. This movement often results in such a change of conditions as destroys the physiological state under consideration. But in case it does not, then the second tendency of the physiological state shows itself. It tends to resolve itself into another and different state.

I may thus summarize the relation of metabolic processes to physiological conditions and processes of behavior by the following table.

TABLE 1.—*The dynamic relations of animal activities.*

The animal as an agent (activity of an agent).	Processes of activity.	Products of activity.
The animal as an agent transforms energy and substance by its metabolic processes. These are accompanied by physiological conditions or states; they constitute a condition of unstable equilibrium. The transformations take place as— (1) Continuous and irreversible processes, as development, differentiation, etc.; or are— (2) Periodic or rhythmic processes, as digestion, sexual activity, etc.	This unstable internal condition tends toward change, resulting in— (1) New conditions; (2) Movement; (3) The processes of behavior: Trial, experiment, investigation, etc.	New states. Movement. Response. Regulation. Adjustment. Relative equilibrium. Learning. Orientation. Data. Concepts. Explanation. Theory. Hypotheses. Ideals.

Changes in the internal conditions are produced also by external stimuli.

The responses of animals to the conditions in which they live are of a composite character. Certain responses, such as the chirping response of a coot within the egg, are inherited and are relatively automatic in character; others are greatly modified by experience, as when an animal "learns," or forms a habit by repeated responses.

The responses of animals to the conditions of existence are the basis for any study of their relations, not only to other members of their own species, but to all elements, living or otherwise, of their complete environment. It is from this standpoint that animals must be considered in estimating their place in the economy of nature; that is, in estimating how they influence one another in an association of animals living together in the same habitat, and in judging of their relation to the succession of animal communities, and even to man himself.

6. THE INTERRELATION OF ANIMALS.

A group or association of animals or plants is like a single organism in the fact that it brings to bear upon the outer world only the surplus of forces remaining after all conflicts interior to itself have been adjusted. Whatever expenditure of energy is necessary to maintain the existing internal balance amounts to so much power locked up and rendered unavailable for external use.—S. A. Forbes.

We have now seen the dependence of the animal upon its environment, as this forms the basis for an understanding of conditions involved in the problem of *maintenance* or the upkeep of the animal. The optimum conditions for prolonged maintenance produce the vital and ecological optima. These conditions imply more than mere maintenance; they mean as well, a degree of favorable conditions which permits the animal to exert an influence or stress upon its environment. As Forbes has said, if all the energy available to the animal is utilized internally there will be nothing left to influence the environment. Metabolic changes show that large amounts of energy and substance are used in maintenance. Under optimum conditions even greater amounts must exist. An animal must not only be able to maintain itself against other kinds of animals but even against its own kind, for the overproduction of its own race will be practically self-destructive. A good example of this kind of influence is seen in the hordes of lemmings which migrate, even into the sea, when overproduction becomes extreme.

The vital and ecological optima are thus to be looked upon as internally balanced, but externally, not as a state of balance or poise, but as a condition in which the animal is exerting stress, pressure, or influence upon its environment, instead of being passive or inert. A group of animals living together in any given condition such as an association, is an assemblage of interacting organisms. The active, free-moving animals collide with each other, with other kinds of ani-

mals, especially the relatively sedentary kinds, and with their environment of plants and the inorganic factors. The relatively sedentary animals are correspondingly bombarded by all elements of their environment. The association, as a whole, is thus in a continuous process of bombardment and response from every possible angle, and just as the individual animal is stimulated and responds, so all the members of any association are stimulated and respond in a similar manner. It is by this form of activity that animals not only maintain themselves but exert a radiating influence.

It will assist in realizing the constant pressure exerted by animals if we compare their activity to the flow of a stream. The pressure exerted by the stream may be realized if by a dam or similar means the current is resisted. Think for a moment of the amount of energy which would be transformed in an effort to prevent animals (or plants) from taking possession of a *favorable habitat*. Imagine an area 10 feet square and think of the effort it would require to prevent animals permanently from invading and establishing themselves in this habitat if no barriers were interposed, and if the means of destruction of the invaders were not so drastic that they materially changed the character of the habitat. Increase the size of the area and the difficulties will increase in geometrical ratio, and the utter futility of such an undertaking will soon be realized. The spreading processes of the gypsy moth in Massachusetts, and of the San Jose scale and the cotton boll weevil, show us in terms of human experience something of the energy expended by these radiating animal activities even when there are strong human economic inducements against such invasions.

When a balanced condition, or relative equilibrium, in nature is referred to we must not assume that all balances are alike, for some are disturbed with little effort and others are exceedingly difficult to change. This distinction is an important one. Once the balance is disturbed the process of readjustment begins. This is a phase of the balancing of a complex of forces. Just what stages this process will pass through will depend to an important degree upon the extent of the disturbance. Slight disturbances are taking place all the time and grade imperceptibly into the normal process of maintenance, as when a tree dies in the forest and its neighbors or suppressed trees expand and take possession of the vacancy thus formed. Disturbances of a greater degree, on the other hand, may only be adjusted by a long cumulative process. This change can progress no faster than the rate at which its slowest member can advance. Thus a forest association of animals may be destroyed by a fire so severe that all the litter and humus of the forest floor is burned. The animals which live in the moist humic layer as a habitat, such as land snails, diplopods, and certain insects, can not maintain themselves upon a mineral soil, rock, or clay. As such a forest area becomes reforested

these animals can only find the optimum conditions when the slow process of humus formation reaches a *certain degree of cumulative development*. Under such circumstances this later stage must be preceded by *antecedent processes*, and restoration of the balance is long delayed. Some adjustments take place so quickly that little can be learned of the stages through which they pass. There are, however, many slow processes which afford an abundance of time for study; in fact some are too slow to study during a lifetime. The processes which are moderately slow are often particularly illuminating because all stages are frequently so well preserved that comparison is a very useful method of study; the slowness of a process has a certain resolving power, as it were, recalling the influence of a prism upon a beam of white light, which reveals many characteristics obscure to direct vision. A study of the processes of adjustment among animals is a study of an important phase of the problem of maintenance. The continued process of response will, if circumstances permit, lead to a condition of relative adjustment, or to a balancing among all the factors in operation.

7. ECOLOGICAL UNITS FOR STUDY.

In the study of animal responses many different units are available, and a brief consideration of these will aid in an understanding of the methods which are useful. Because the animal body has been found to be composed of a single cell or a multitude of cells, a common belief has grown up that the cell is the natural unit for study. This opinion seems to be due to overlooking the fact that there is just as much reason for considering the *whole animal* as the unit. The unicellular animals are *whole animals* as truly as they are cells, and in multicellular animals the activity of single cells means little independently of the animal as a whole. It thus seems that ecologically at least the smallest valuable unit for study is the *individual animal*. The responses of the individual, as a kind of animal, to its condition of existence form the basis for what may be called *individual ecology*. Animals which are related by descent from common ancestors, as a community of social animals (e. g., an ant colony), or taxonomic units, such as genera, families, orders, etc. (e. g., fish, birds, catfishes, and salamanders), are also units which may be studied ecologically. Some of these hereditary units are, ecologically, fairly homogeneous, as, for instance, when a taxonomic unit is equally distinct ecologically: e. g., the woodpeckers with their arboreal habits. In other cases the taxonomic unit contains animals of great ecological diversity, as in the case of beetles, which possess almost unlimited ecological diversity, including littoral, aquatic, subterranean, and arboreal

habitats, and parasitic, herbivorous, and predaceous habits. The study of ecology, upon the basis of such a unit, may be called *aggregate ecology*. Still another unit is available, based upon the animals which live together in a given combination of environmental conditions, as in a pond, on the shore of the sea, in a cave, within the bodies of animals, on the floor of the forest, or in the tree tops, etc. The animals found living together in such conditions form an *animal association* or a social community, and the study of the responses of such a community is the province of *associational ecology*.

8. THE ANIMAL ASSOCIATION.

In the study of the animal association as a unit, we consider it as an agent, whose modes of activity, or responses, are of primary interest. We desire to know the kinds of animals which compose the community, the optimum and limiting influences which control its activity, the character of its responses, and the orderly sequence of changes in the environment to which it is responding.

The maintenance of an association depends upon the maintenance of the individual members which compose it, just as the maintenance of the entire animal depends upon the activities of the cells. There is the same basis for speaking of the responses of the association as there is for speaking of the responses of the individual. The association can continue to exist indefinitely only in such environments as possess, in available form, substance and energy for its individual members. The activities of the individuals transform energy and substance, producing growth, development, multiplication, and behavior. The persistence of an association in a given habitat brings about the formation of certain waste products, which if not changed or transformed at a certain rate, or transported from the environment in some way, tend to limit the optimum activity of the individuals and of the association. In the association, as in the individual, there must be an internal relative balance before there can be such a surplus of energy that the association can radiate or exert outward stress or pressure. An association which is only maintaining itself is not at an optimum, for in this latter condition there is a surplus of energy, and the activity, rate of multiplication, and favorable development under normal conditions are favorable to the extension of the association. The pressure which such an association exerts is shown by the progressive extension of its range of influence. By the active movements of the animals, by the activity of the environment, or by both together, they tend to invade other habitats and areas, and in such of these as afford favorable conditions they tend to survive and extend the area of the association. From the

standpoint of the association the behavior of these active pioneering animals corresponds to the trial activities in the behavior of the individual animal. These activities are not different in kind from those which are involved in normal maintenance. They are those which form the initial stages in the establishment and extension of the association in a new locality or the reestablishment in an old one, and thus lead to a sequence or succession of associations. Ecological succession thus consists in an orderly sequence or series of associations which occur successively and form a genetic series.

9. ASSOCIATIONAL SUCCESSION.

A succession of associations takes place either through a transformation of older ones, or through the origin of a new one on a surface which has been newly formed and has had no population. A favorable habitat without a population of animals is comparable in some respects to a vacuum; it exists as a condition of unstable equilibrium which tends to change toward a more stable state. The active life of animals tends to lead them into all possible habitats, and where they find the conditions favorable for existence they tend to survive and thus bring about the establishment of an association. Each association, like the individual animal, has a certain amount of unity and tends to maintain or perpetuate itself. But the stability of associations is only relative, and some are much more stable than others. Naturally the unstable ones are those which show succession most readily. Thus if we destroy a few trees in a hardwood forest and produce a glade, a large number of the characteristic animals of the dense forest will disappear and be replaced by animals which normally frequent open places; then in a few years sprout-growth and young and suppressed trees will change the conditions so much that the kind of forest animals which were eliminated for a time will begin to return; and when the new growth is replaced by the mature forest the animals of the mature forest will return and a new equilibrium will be formed. In such a forested region the glade is to be looked upon as an unstable condition, which through a succession of associations will later arrive at a relatively stable condition, which is able to perpetuate itself indefinitely under existing conditions. Such an association is considered a *climax*, or the culmination of a series of successions under existing conditions. The succession of associations leading to a climax represents the process of adjustment to the conditions of stress, and the climax represents a condition of relative equilibrium. Climax associations are large units, and are the resultants of certain climatic, geological, physiographic, and biological conditions.

THE DYNAMIC RELATIONS OF THE ENVIRONMENT.

1. INTRODUCTORY.

In the preceding section we have seen that to understand animals we must consider them as active living agents which are constantly changing and responding to their environment. That the environment of animals should also be studied as an *actively changing medium* has not been so clearly recognized by students of plants and animals as one might anticipate from its importance. Some students feel that the study and understanding of the environment is not a part of zoology, or at least not an essential part. Furthermore, to some of these students at least, the environment seems largely chaotic, a confused unwieldly mass with no evident favorable point of attack. This view is quite natural to those who have had no training and practical experience in recognizing the "orderly sequence" or laws of environmental changes, and particularly to those who do not feel that environmental relations are an essential part of their subject. By many such students the environment is viewed in a manner comparable to the prevailing chaotic views on weather before meteorology became a science, or on taxonomy before Linnæus, or on geology before Lyell. If one has serious doubts on this point, he need only turn to the standard treatises on zoology and search for a comprehensive and adequate recognition and utilization of the orderly and regulatory character of the environment as an essential part of the subject.

The fallacy of this position has been well expressed as follows by Brooks (1899):

> I shall try to show that life is response to the order of nature. * * * But if it be admitted, it follows that biology is the study of response, and that the study of that order of nature to which response is made is as well within its province as the study of the living organism which responds, for all the knowledge we can get of both these aspects of nature is needed as a preparation for the study of that relation between them which constitutes life.

Later he says:

> But if we stop there, neglecting the relation of the living being to its environment, our study is not biology or the science of life.

No one seems to have attempted to refute this; naturally an easier path is followed—to ignore it. Perhaps up to the time of the present generation there has been some excuse for this confusion; but now the responsibility does not rest upon students of the physical and vegetational environment but upon students of animals, because the former students have arranged their scientific data in a manner which clearly shows the orderly lawful sequence of changes in environmental activities. This should form the basis for a study of the

corresponding series of changes which take place within the animal, and also be the basis for a study of the reciprocal responses taking place between the animal and the environment.

In this section an outline will be given of some of the most important phases of environmental changes in inland areas viewed as lawful and orderly, particularly those changes which influence animal habitats.

2. THE DYNAMIC AND GENETIC STANDPOINT.

Since Lyell taught the scientific world that a study of processes now in operation is the key to an understanding of the present as well as of the past, the *process* method has been slowly but inevitably penetrating to the utmost subdivisions of inquiry. With the progressive appreciation and use of this method its efficiency has been increased. Its progress has been the most rapid where the principles of its application have been most clearly understood. As models become known in each field of work others will find the method much easier to apply, and for this reason it is desirable that such examples become fairly numerous and widespread.

In the application of the process method to an imperfectly understood subject, and particularly to a complex one, it is desirable to consider the subject as a *unit* or entity. This unit may then be regarded as an agent whose process of activity is to be studied, for the activity of an agent gives us a process. Thus an organism, a plant society, or an animal community is a very complex unit or agent, which largely through chemical energy, under conditions of a normal environment, responds in an orderly sequence of changes. The environment changes, the internal conditions of the animal change, and so do the corresponding responses on the part of the animal. When all of these changes are studied as *orderly processes*, we are able to see the advantage of this method of study. It is desirable to investigate all phases of animal responses in this manner, such as growth, development, heredity, etc., in order to determine the causes and conditions of this orderly sequence. As a rule our recognition of the *orderly sequence* or laws of action or succession precedes our knowledge of the causes and conditions of the sequence. This order of sequence is thus of fundamental importance and must be recognized before it can be investigated or explained. This method of studying the activity of agents, the character of their processes, constitutes the dynamic standpoint.

When the dynamic relations of an agent have been investigated, the orderly sequence of its responses established, and the causes and conditions of its activity determined, it is then possible to explain fully the origin of genesis of its activities. The *genetic method* is the study of origins in *terms of the processes involved*, and therefore the classification of facts genetically implies a knowledge of the proc-

esses involved in their origin. There are thus many degrees or stages in the development of a genetic classification, the first step of which is to determine the orderly sequence of changes. In a certain sense, in its broadest application, the process method is universal and includes the genetic, but until their mutual relations become clearly recognized and are generally understood both should be emphasized.

Particular attention should be called to the fact that the activity of an agent results in a process, and processes give us the *laws of change*. Many processes are reversible; that is, a process may go forward in one direction and then become reversed and proceed in the opposite direction. Other processes are nonreversible, and operate in only one direction, being in a sense orthogenetic, as in the later stages of the ontogenetic process.

Let us summarize the main characteristics and principles involved in the dynamic and genetic method. They have been well expressed by Keyes (1898), and for my purpose are arranged as follows:

> A truly genetic scheme for the classification of natural phenomena thus always has prominently presented its underlying principle of cause and effect. * * * To begin with, an adequate scheme should be based directly upon * * * agencies. * * * All products must find accurate expression in terms of the agencies. * * * The primary groupings of the * * * processes must be based, therefore, upon the manner in which these agencies affect the * * * materials. * * * Constructive and destructive agencies can be recognized only when the phenomena are made the basis for the scheme. Processes are merely operative. If coupled with products at all, in classification, all must be regarded as formative or constructive. The product's destruction, its loss of identity, is wholly immaterial. The action of agencies is merely to produce constant change.

Van Hise (1904) has formulated other principles of the process method as follows:

> The agent is the substance containing energy which it expends in doing work upon other substances. The substance upon which work is done may thereby receive energy and thus become an agent which does work upon other substances; and so on indefinitely. Indeed, the rule is that one process follows another in the sequence of events, until the energy concerned becomes so dispersed as to be no longer traceable. Theoretically this goes on indefinitely. * * * We have seen that the action of one or more agents through the exertion of force and the expenditure of energy upon one or more substances is a geological process. It is rare indeed, if it ever happens, that a single agent works through a single force upon a single substance. * * * If geology is to be simplified the processes must be analyzed and classified in terms of energies, agents, and results. Each of the classes of energy and agent should be taken up, and the different kinds of work done by it discussed. * * * The general work of each of the agents and the results accomplished should be similarly considered. Not only so, but the work of the different forms that each of the agents takes should be separately treated. Thus, besides considering the work of water generally, the work which it does both running and standing must be treated. The first involves the work of streams; the second the work of lakes and oceans. This involves the treatment of

streams as entities. * * * The treatment of the agents will be more satisfactory in proportion as the work done by each of the forms of each of the agents is explained under physical and chemical principles in the terms of energy.

Viewed from this standpoint it is remarkable how many of our current zoological conceptions are essentially static and how confused are our conceptions of the process method. Physiology is supposed to be devoted solely to processes, yet physiologists use the terms anabolism and katabolism, constructive and destructive influences, and, likewise, zoologists frequently use the expressions "the friends" or "the enemies" of animals—a dual terminology which has a certain utility but which exists mainly on account of the static conceptions of organic relations.

The dynamic or process concept is a difficult one to attain, and to apply in all cases, as any one will soon learn if he strives to do this consistently; and yet as a scientific ideal there can be no doubt that it has the same superiority over the older static methods and point of view that an explanation has over an empirical description.

3. DYNAMIC AND GENETIC CLASSIFICATION OF ENVIRONMENTS.

In the natural history sciences we have two main sorts of classifications of phenomena, those which we call "natural" and those which we call "artificial." Natural classifications are those in which the basal criteria are of *origin*, the method of processes or genesis. A classification of lakes upon the basis of the *processes which operated in their origin*—crustal movements of the earth, the meanders of streams, the work of an ice sheet, volcanic activity, etc.—would at the same time furnish an *explanation of them in terms of their origin*. Artificial classifications are those in which the criteria are arbitrarily chosen. Any character may be made the basis for an artificial classification. Thus lakes may be classified upon the basis of their size, depth, color of the water, distance from cities, number of boats upon them, etc., but such classification would not furnish the basis for a *scientific explanation of lakes*. The artificial is often useful or convenient for a special purpose; the genetic is illuminating from the standpoint of *scientific interpretation*. This method may be applied to any kind of environment, physical, physical and biological combined, or solely biological. To the degree that the environment is dominated by the physical conditions the laws of physical change and physical genesis will preponderate in the origin of such environments, and corresponding relations apply to biological environments.

The dependence of the genetic method upon causes and conditions makes it impossible to divorce it from the local conditions. This is at once the strength and weakness of this method, for it is particular, and generalized averages mean little because origins are different un-

der different conditions; this is the key to *individuality*. Thus streams viewed as stages in the progressive transformation of a liquid medium for life, may be formed in many diverse ways, and for this reason the general principles of the method of genesis may be expressed most simply in an *ideal case*. Genetic series are *unending*, they extend into the past and will continue in the future. The point of departure for study must therefore be arbitrarily chosen, and the more nearly a natural basis can be approximated the simpler its application becomes. For this reason a cycle will be followed here which begins with a condition of *stress*, advances through the *process of adjustment to strain*, and reaches a *condition of relative equilibrium*. The starting point in such a cycle we will consider as the *original conditions*, and the later activities as the derived ones. The original conditions we will assume to be an uplifted undulating plain, composed of relatively homogeneous materials, in a humid climate, and covered by a varied vegetation, including trees. The elevated condition of the land produces a condition of *unstable equilibrium* or *stress* for the rain falling upon its surface; and, furthermore, the vegetation will tend to spread over the entire surface and thus exert a certain pressure also. These original conditions, are, therefore, unstable and destined to change, and mutually to influence and regulate one another.

If we now imagine the rain "turned on" under such conditions, what are the main processes which will operate? The rain falling in a depression will be supplemented by that which drains from the elevations; thus, through the *agency* of running water a standing-water habitat will have its origin. With this concentration of water will come also a burden of débris from the upland; and in this way the "constructive" and "destructive" processes will begin at the same time. Plants will invade such a depression and add their remains. Some of the depressions will overflow and the outflowing streams will cut down the outlet to progressively lower levels and ultimately drain the basin. On the other hand, inwash and organic débris may together accumulate at such a rate as to raise the level of the basin above ground water and thus transform the conditions to that of land. The progressive stages of the *process of degradation* thus favor the transformation of the depression and a progressive formation of lakes, which are converted into ponds and swamps, and ultimately, with drainage, to dry land. For depressions we thus get a genetic series which we may call the lake, pond, and swamp series. This does not classify the depression series according to size, depth, character of water, etc., as in an artificial classification, but in the *order of their development or genesis* through the *agency* of running water. Accompanying this *sequence* there are of course changes in size, depth, etc., but these are subordinated in the classification to the

developmental sequence centering about the process of the degradation of the land by the agency of running water. This is therefore a classification of environments, not on the basis of the product, as it might appear from calling it a depression or standing-water series, but upon the *basis of the activity or processes of the dominant agent.*

We will assume that all the lakes, ponds, and swamps, due to the original relief of the land, become drained and constructively converted into streams or dry land. Let us consider the streams, particularly those which did not develop from the lake, pond, and swamp series, in order to consider them in their simpler conditions of development.

The first shower on the new land surface, or the beginning of a cycle, forms an extensive ramification of small streamlets, their dendritic branches flowing down all slopes. With the confluence of the smaller branches the progressively larger trunks are formed, and with their increase in volume, cutting progresses; but all traces of this stream itself tend to vanish soon after the shower is over, although some water may linger in pools in the deeper depressions. These conditions form an *initial stage* in the development of the activity of running water as an animal habitat. These temporary streams are rain waters intermingled with dust from the air and soil from the ground. Since, viewed chemically, such waters have not existed as a liquid long enough to dissolve much gaseous and solid material, they represent a relatively original condition, or an initial stage in the chemical development of the stream as a medium for living animals. Again and again these showers are repeated, and where there is a slight variation in the hardness of the substratum small pools are formed on the softer materials, where erosion is more rapid. In these pools it is possible for some aquatic or amphibious animals, of marked powers of dispersal, to become lodged, or even entrapped, as in the case of animals which migrate up the stream during its temporary flow; such pools, in fact, may be reached even by individuals from the ground water.

Finally these temporary streams cut down to the ground-water level and become permanent. Such a stream then, in addition to the fresh rain water which it receives with each shower, has a permanent supply of ground water. This water, having filtered through the soil, contains both gas, particularly CO_2, and minerals, and thus as a solution differs much from rain water. The composition of ground water varies much with the chemical differences of the substratum. Such water generally contains enough substance in solution to be a favorable medium for plant growth, such as algæ—aquatic pioneers which are comparable to the lichens in their invasion upon bare rock. But the temporary flow of water is still dominant, and will remain so until the supply of permanent ground

water is of such a volume that, having a good current, it rushes over the obstacles in its path; then a permanent brook has been evolved, and a permanent rapid-water habitat has originated.

As the erosion of the stream advances, organic débris not only multiplies indigenously in the water, but it is also washed and blown in, and through its decay the composition of the water is changed, particularly in the amount of CO_2 present. This gas causes the water to take into solution a greater amount of lime; and at the same time the agitation to which it is subjected while dashing over obstacles or flowing over falls increases the amount of oxygen present, a process further aided by the oxygen set free in it by water plants. Carbonic acid, moreover, is set free by the rapids and falls. It is thus very evident that the chemical processes are undergoing an important development as the stream progresses, since there are going on both the process of gaseous equilibrium with the air, and an increase of the solids in solution. The stream is progressively becoming a more favorable or enriched culture medium for organisms. The rapidly flowing water which characterizes the brook is the predominant physical feature of this environment, the stretches of relatively quiet water which form the pools, between the more rapidly flowing parts, anticipating the kind of conditions which are destined to increase with the transformation of the brook conditions into those of a creek. With the progress of development in drainage a brook is progressively transformed by the processes of erosion into a creek. Here the rapid-water conditions are more nearly equaled by a corresponding enlargement of the pool or the quieter stretches of water, where the finer sediments are deposited and the animals dwelling on the surface film or in the mud and sand, find suitable conditions. The falls and rapids which characterize the brook are exceptional in the creek, but may linger where the rate of change has been very slow on account of the resistance of the substratum. The alternation of rapid and slower water, which characterizes the creek stage, with the preponderance of the relatively rapidly flowing water, is gradually transformed into that of a river, where the water flows at a slower rate and rapids and falls have as a rule become extinct, and where a condition of relative chemical equilibrium has also been reached. Here the burden of coarse débris is at a minimum, and the surface, sides, and bottom of the stream have become differentiated as relatively distinct habitats. With progressive approach toward base level all conditions of the environment tend to become more stable and equalized until the stream erodes to tide level, becomes brackish and finally as salt as the sea itself, and reaches an equilibrium determined by the dominant animal environment upon the earth—that of the sea.

We have now outlined the developmental sequence of wet depressions, the lake-pond-swamp series, and the running water, the brook-creek-river series, these two series including the main inland animal environments in a liquid medium in a humid climate. We have yet to consider the animal environments of land animals proper, those which live in the gaseous medium of air. The complexity of conditions upon land is much greater than that in water, either fresh or salt. In other words the land habitats are the most complex on earth. For simplicity in handling this involved problem, an ideal series will also be followed, and instead of attempting to discuss all the principles involved, only such will be mentioned as may be illustrated by a single example. This will serve to show the application of the method. We shall consider the process of degradation of the land, such as might be developed during a topographic cycle of erosion, and as applied to a snowcapped conical mountain in a temperate humid region.

Let us consider the series of processes which operate upon such a mountain. The snow and rain which fall upon it are in unstable equilibrium, the snow creeps or plunges down the slopes, and the water flows down. In the zone of ice and snow physical and mechanical changes preponderate; but at lower altitudes, with the melting of the snow and ice, on account of the higher temperature, chemical changes become more prominent and supplement the mechanical work of running water. Here, also, plants and animals become an important factor in modifying the processes of change by hastening or retarding the processes of degradation. We thus see that on different parts of a mountain there are important modifications in the processes of degradation. The same general processes which operate to form lakes, ponds, swamps, brooks, creeks, and rivers, are also at the same time producing changes in the land habitats. The entire surface of such a mountain is undergoing change, but because of the concentration of degradative progress near its base, particularly on account of the concentration of the drainage there, ravines and valleys develop here more rapidly and converge toward the main divide, the mountain top. As these ravines and valleys enlarge, the mountain is lowered; and ultimately all is reduced to a plain, and to baselevel. The condition of stress which existed upon the slopes of such a mountain as degradation progressed, became relatively adjusted *at that place*, but where the degraded materials were deposited a stress was *becoming cumulative*, and it is this ever-changing adjustment of stresses which makes natural processes unending.

With the degradation of the mountain, progressively higher zones are lowered; the snow cap disappears; the region above the tree limit, and later the lower parts, are spread over a large area, and the mountainous character is largely gone. In this manner and at the

same time as the land is degraded to a lowland by running water, in the water itself a series of habitats is developing, and thus *all the environment is being transformed, along relatively distinct but mutually interdependent lines, toward the same general direction or condition*—a relative equilibrium resulting from the balancing of all stresses near sea level.

In the preceding discussion no emphasis has been placed on the fact that degradation of the land is only a part of a large cycle of activity, and that the deposition of the degraded materials may be a cause of so much stress as to initiate an elevation of the land. If the heavy soluble materials from the land are washed into the sea and only lighter materials remain behind, the increased stress resulting between the sea and the land will tend to elevate the lighter areas until an equilibrium is established between the heavy sea and the lighter land: therefore, some crustal movements, at least, may be complementary phases of the degradation of the land. The elevations and depressions of the surface of the land with regard to the sea level may thus initiate new cycles of transformation in all environments. These processes do not need amplification here, although they should be noted: but this lack of amplification does not imply a minor influence of this factor. Still another cycle may be initiated by the processes of vulcanism, a factor the influence of which is easily overlooked in large parts of the world but in others is very prominent. Only one more comprehensive physical factor will be mentioned; that due to alterations in the atmosphere—climatic changes. Although the temperate humid climate has been made the basis for the preceding discussion, it must be remembered not only that there are other kinds of climates, but that these undergo transformation or changes from such extremes as the cold arctic deserts on the one hand, to the dry hot deserts on the other. Within this great amplitude of climatic possibility is found one of the greatest causes both of complexity in land environment and of many local differences in the transformation of habitats.

To simplify this sketch of the operation of the physical features of the environment the organic factors have been neglected, and these should now be considered. On account of the ultimate dependence of animals for food upon vegetation, many intimate relations exist between plants and animals; furthermore, in addition to the food relations there are many other important ones, such as the physical and chemical influence of the vegetation upon the soil, its influence upon the temperature and humidity of the air and on light; and, finally, there is qualification of these influences by the different kinds of vegetation. A vegetational cover of grass has a very different effect from one of shrubs or a forest cover; conifers and hardwood forests differ in effect also; and the succession of plant societies varies, not only with

different kinds of vegetation but also in different climates, and with different physiographic conditions. As Cowles (1911) has shown, there are several cycles or series of successions of vegetation. Many of these changes are dependent upon physical conditions which are equally potent in their influence upon animals. Thus physical and vegetational changes in combination influence animals directly and indirectly, and in the conditions due to this fact we find the basis for the important control which vegetation exerts upon animals.

Animals themselves form an important part of their own environment, not only in their relation to their own kind, as mates or as progeny, but also as members of an animal community whose members must adjust their activities to one another through symbiotic, competitive, or predatory relations. If any animal becomes abnormally abundant, that is, more numerous than the conditions can support, this number in itself becomes a weakness, through the positive attraction of the organisms (plant and animal) which are able to prey upon it, and soon the normal abundance is restored. For example, in a coniferous forest, bark beetles (*Scolytoidea*) may increase to such an extent that the forest is largely destroyed, and a succession is produced in the vegetation as the conifers are replaced by a growth of aspen and birch. As a result of this destruction of the kind of food and habitat essential for the next generation of beetles, a proper habitat is lacking, and the restoration of the normal number of beetles is hastened. This same example also shows how one kind of animal may influence the character of a whole community by its control over the vegetation.

The influence of man must be looked on from the same standpoint as one views the activity of any other animal; as that of a member of an animal community. He hastens and retards the changes in his environment as do other animals. In general his early methods are predatory; he reaps where he does not sow; but later the milder competitive and symbiotic relations and the constructive or productive aspect become more prominent. Civilization is an attempt to make the environment "to order," but as yet man has not learned how to produce a permanent "optimum" along the lines of an ecological community. As has already been said, to understand man we should view him as an integral part of an ecological community, as one member of a biotic community of plants and animals, or at least of an animal community which includes all animals that are influenced by man—and not consider him, as some students do, as a distinct entity with little regard to his animal and plant associates.

The main features of the preceding discussion may be summarized as in the following table:

TABLE 2.—*The genesis and formation of inland habitats in a humid climate and the dynamic status of the processes.*

Dynamic status.	Phases in the formation of inland environments.				
I. Unstable equilibrium—condition of stress or pressure.	*Original conditions;* elevated land area, or new land surface, or beginning of new cycle.				
II. Process of adjustment to stress or strain.	*Process of formation* of habitats: all habits are constructive.				
(The following are examples of the major processes): 1. The processes of degradation of the land. 2. The processes of adjustment to climate. 3. The process of the establishment of biotic (plant or animal) dominance.	Biotic sequence in all habitats and all series, as a part of the animal environment.	Initial phase	Intermediate phase		Dominant phase
	Sequence of standing-water series (depression series); reversible series.	Lake	Pond	Swamp	Drained land
	Sequence of land habitats, elevation series; reversible process.	Upland	Lowland		Base-leveled plain
	Sequence of stream habitats, depression series; partly reversible.	Temporary stream	Brook	Creek	River
III. Relative equilibrium.	*Derived conditions;* lowland area, old land surface (base-leveled to the marine environment), end of a cycle, or dominance under relatively stable conditions.				

The preceding discussion is based upon the conditions of a humid climate, but the semiarid and the arid climates should also be touched on. In time, as ecological studies are extended to all kinds of land areas, it will be possible to formulate all of the general principles of the origin or process of development of land habitats; but at present vast areas of the land have never been observed by a zoologist from a modern ecological standpoint. Most of the ecological studies of animals have been carried on in a humid climate, only slight attention having been given to the ecological relations existing in an arid climate, and still less to those in alpine and polar regions. After the

humid regions have been better studied, the arid regions will probably be the next to be carefully investigated. The plant ecologists, by their studies in these regions, have already furnished important facts, preparing the way for the animal ecologist, because they have investigated both the physical and vegetational conditions upon the prairies and plains of the West. If the regions of progressively increasing aridity are examined, there will be found to be a corresponding series of changes in the animal habitats. The standing-water series of habitats found in such a series, in contrast with those of humid regions with fresh-water lakes, ponds, and swamps in addition to the temporary fresh waters, are alkaline and salt waters, and we find an extensive series ranging from Great Salt Lake, Salton Sea, and Devil's Lake, to strong briny pools and alkaline mud flats. These are, of course, as capable of a genetic treatment as are the corresponding fresh-water bodies of humid areas. The stream series is also present in the arid region, but it exists under conditions quite different from those in humid areas. The through-flowing streams are *relatively* independent of local conditions because their main supply of water is from the mountain; but they are nevertheless much modified by the character and amount of the burden which they carry during the time of high water, and they tend to become clogged at low-water stages. The chemical composition of such waters is quite different from that of regions continually leached by rains. The small streams flowing from the mountains, whose diminishing volume does not allow them to traverse the arid regions, succumb, and disappear in the dry earth—examples of a second degree of dominance of the desert or plains. But the truly characteristic streams of the arid regions are those primarily dependent upon the desert conditions. Such streams are well within the arid regions and are dominated wholly by them. They are solely of a temporary character, and correspond to the initial stage of stream development, the temporary stream, in a humid climate. In an arid climate, however, development does not proceed beyond this early stage, and the degradation and base-leveling of the land is due to the combined influence of water and the wind.

On land the movements of the soil by the wind, as in the sand-dune regions of true deserts, show us a characteristic condition; in a more humid climate, however, the dunes would tend to become anchored by vegetation. Other soils than sand are also blown about. The extreme of dry desert conditions must be looked upon as the ultimate or climax condition, a condition of relative equilibrium, under present climatic conditions, for certain regions. A slight departure from these extreme conditions is seen in such localities as receive most abundant showers during the growing season for vegetation. These are able to influence the development of the drainage

only in a minor way, but they moisten a shallow surface layer of soil and permit the growth of short grasses, such as the buffalo-grass (Schantz, 1911:40). Very recently another important source of water in the arid regions has come to be recognized. This, McGee has shown to be the subsurface or artesian waters which come up from below; and this is an important supplementary source of moisture in extensive areas in the arid West (McGee, 1913), where the evaporation is large. It is not unlikely that even in humid regions where the soils are very sandy, as upon the Coastal Plain, and where the strata dip in such a manner as to favor an underflow of water, this supply may be of considerable importance to the biota. With a greater rainfall during the growing season, permitting a relative humidity greater than on the short-grass area of the plains, a deeper-rooted vegetational cover gives us the long prairie grasses of the eastern prairie.

As soon as the physical conditions permit a growth of vegetation this material becomes an environmental factor which reflexly modifies the physical conditions of the air, the soil, and the animal habitat. This is shown to a marked degree in the humid area of the southeastern United States, where the rainfall, greater than that on the arid plains and prairies, favors the development of a forest cover. Such a forest not only tends to retard evaporation but also acts as a sponge, and by its vegetable débris and loose soil retards the run-off. In this manner not only are land habitats influenced but this conservation of moisture tends to prolong the duration of temporary streams and to stabilize the flow of permanent ones; and, further, through the same influence the ground-water level declines slowly, and bodies of standing water are also influenced. Thus all the more important habitats are to some degree regulated and made more stable by a forest cover.

The foregoing discussion and examples, selected from the activities of animals and changes in their environments, are varied enough to show how diverse are the applications of the process method to investigation. The general idea is easily grasped, but to make the dynamic method a regular habitual procedure in investigation is truly difficult, so difficult, indeed, that there is reasonable ground for doubting if this method can be mastered without a practical application of it to a concrete problem, at the same time giving special attention to the method of procedure.

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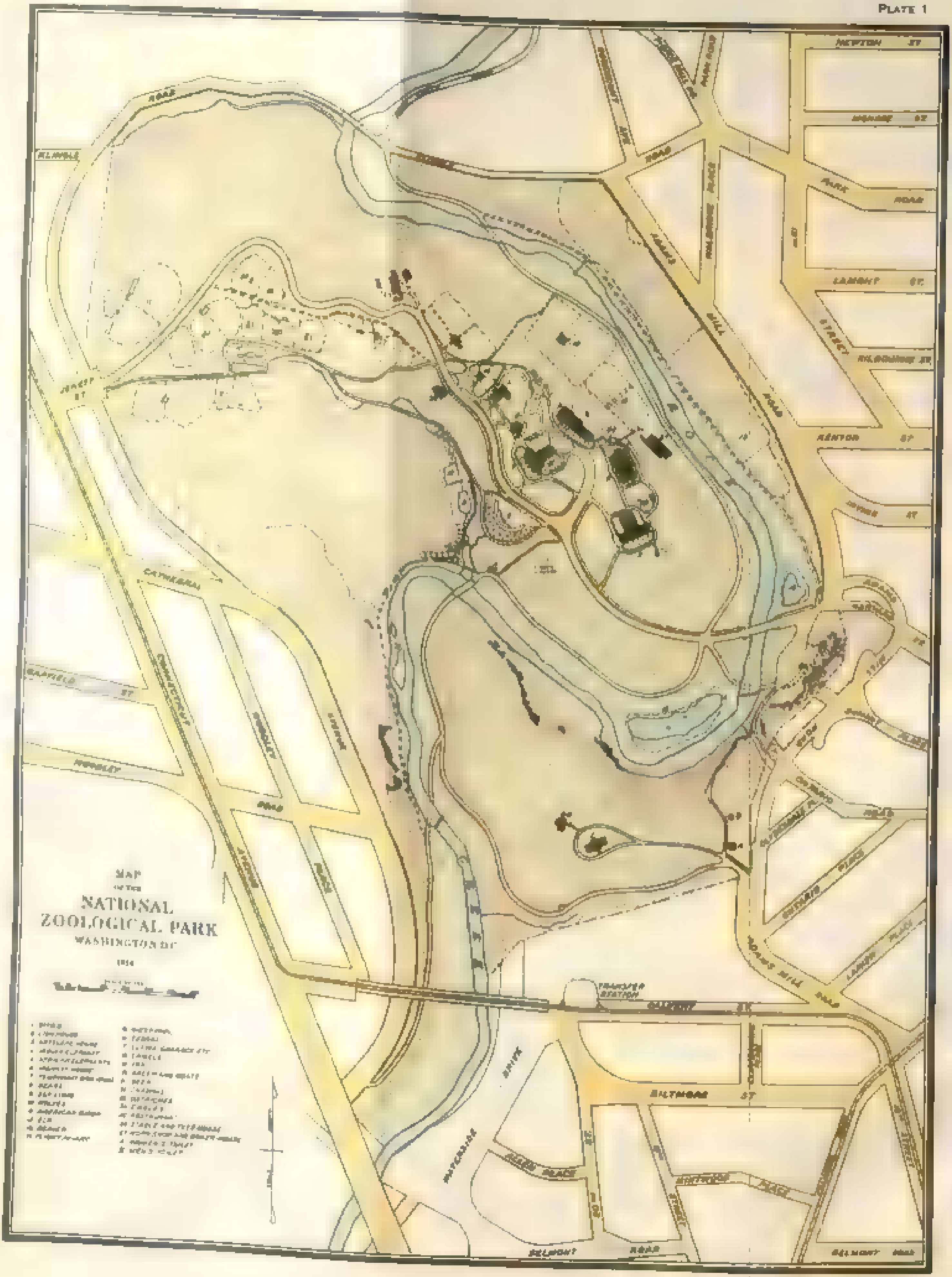

MAP
OF THE
NATIONAL
ZOOLOGICAL PARK
WASHINGTON D.C.
NEWTON ST.
MONROE ST.
PARK ROAD
LAMONT ST.
KILBOURNE ST.
KENYON ST.
IRVING ST.
ADAMS MILL ROAD
CATHEDRAL
GARFIELD ST.
WOODLEY
ROAD
TRANSFER STATION
CALVERT ST.
BILTMORE ST.
BELMONT ROAD
ONTARIO ROAD

THE NATIONAL ZOOLOGICAL PARK: A POPULAR ACCOUNT OF ITS COLLECTIONS.

By N. Hollister.

[With 46 plates.]

The National Zoological Park, in the city of Washington, was established by an act of Congress approved April 30, 1890, "for the advancement of science and the instruction and recreation of the people," and was placed under the direction of the Smithsonian Institution. Some changes have been made in the original boundary line, and the area now included within the park comprises 169 acres. The park is located in Rock Creek Valley, a district admirably and peculiarly suited for the purposes for which it was selected.

At the time of its establishment the park was some distance from the city proper, but now it is well within the residential district of northwest Washington, almost surrounded by dwellings, and is easily accessible from the heart of the city. No more beautiful site for a zoological park could be desired, and within the fences of this picturesque tract may be found conditions suitable for many of the forms of animal life. The borders of the valley are heavily wooded, and the vegetation in summer almost entirely shuts off the view of the surrounding country. The more open hills and rolling slopes of the interior, where most of the exhibition buildings are placed, are covered with firm sod and excellent lawns, and winding through the length of the valley is picturesque Rock Creek, an affluent of the Potomac River. Systems of automobile roads and bridle paths are maintained throughout the park and walks traverse its most frequented parts.

A collection of about 1,400 living animals is, of course, the feature of the park. There are numerous paddocks and ranges for buffalo, deer, and other large mammals; lakes and pools for waterfowl, seals, beavers, and other aquatic species; outdoor cages, some of large size, for hardy birds and mammals; and houses and shelters for species requiring special care or heated quarters during the winter months. The lion house, near the center of the collection, is at the summit of what is generally known as "lion house hill." In this

building are most of the larger cats, the hyenas, the hippopotamuses, and some tropical mammals. Here also are most of the reptiles. Near by are the monkey house and the bird house, and to the north the antelope house, elephant house, and zebra house. Outdoor yards and cages are placed throughout the park in situations favorable to the comfort and health of the various species exhibited.

The interest of the public in the National Zoological Park is attested by the number of visitors. In 1916 and in 1917 the attendance was over 1,000,000 each year, with a daily average of over 3,000 visitors; and in 1918 a total number of 1,593,227 people were admitted to the grounds, a daily average of 4,365. Although the Sunday and holiday crowds are largely composed of residents of the District of Columbia and near-by States, the week-day attendance is in a large measure made up of visitors from the country at large. A large share of the enormous number of tourists to Washington visit the Zoo and the sight-seeing cars now regularly include the park in their itineraries. Many people are attracted to the park on account of its walks and drives, and as the entire area is a carefully protected sanctuary for wild birds and flowers many nature classes from the schools visit it on their field excursions.

The grounds and buildings are open each day in the year, and admission is always without charge.

MAMMALS.

The mammals (class Mammalia) comprise those creatures commonly known as "animals." They are usually distinguishable from other vertebrates by numerous well-known superficial characters and are briefly defined technically as warm-blooded vertebrates with hair,[1] and with glands in the female for the secretion of milk for the nourishment of the young. Mammals offer a great range of variety in size, general appearance, and mode of life. The elephant, whale, mouse, shrew, and bat include examples showing extremes in bulk and habit. The vast majority of the mammals usually exhibited in zoological gardens belong to the subdivisions of the class known as the ungulates (hoofed mammals), primates (apes, monkeys, and lemurs), rodents (gnawing mammals), carnivores (flesh-eaters), and marsupials (pouched mammals). In the National Zoological Park good collections of numerous species of these groups of mammals may be seen and studied to advantage. A few representatives of another group, the Edentata, which includes the sloths, anteaters, and armadillos, are also shown.

[1] "To define a mammal as a vertebrate with hair would be an entirely exclusive definition; even in the smooth whales a few hairs at least are present, which may be reduced to as few as two bristles on the lips" (Beddard).

MONKEY HOUSE.

SEA-LION POOL.

THE GREAT FLIGHT CAGE.

THE UNGULATES, OR HOOFED MAMMALS.

Modern systematic mammalogists divide the existing "hoofed animals" into four orders—the Proboscidea (elephants), Hyracoidea (hyraxes), Perissodactyla (horses, tapirs, and rhinoceroses), and the Artiodactyla (cattle, sheep, antelopes, deer, camels, swine, and hippopotamuses). The Perissodactyla are called the "odd-toed" ungulates, and usually have an uneven number of toes; as the existing horse with one functional toe, and the rhinoceros with three. The main axis of the foot passes through the third digit. The tapirs, although having four toes on the fore limb, have only three behind. The Artiodactyla are known as "even-toed" ungulates and have either two or four toes on each foot. These include the true "cloven hoofed" animals.

The ungulates are important and popular mammals in zoological parks and are peculiarly suitable for exhibition purposes because many species can be shown in open yards or paddocks which approximate in many instances the natural surroundings inhabited by the animals. No less than 50 species are usually shown in the National Zoological Park, many of which are represented by small breeding herds.

THE ELEPHANTS.

There are many points of difference between the Indian elephant (*Elephas maximus*) and the African elephant (*Loxodonta africana*), but the most conspicuous mark to separate them is the considerable diversity in the size and shape of the ear, that of the African elephant being much larger than the ear of the Asiatic species. Both kinds are divisible into a number of forms, no less than 11 subspecies of the African elephant having been recognized by one authority. African elephants attain a greater bulk than their Asiatic kindred, but are not commonly seen in shows or parks, almost all the elephants exhibited in circuses being of the Indian species.

Perhaps no single animal in the park was better known to the people of the vicinity of Washington than "Dunk," an Indian elephant. Hundreds of the present day business and professional men of the District knew "Dunk" when they were children. He was the first animal to be placed in the Zoological Park when the present site was occupied, and was a gift from James E. Cooper, the proprietor of the Adam Forepaugh Shows, April 30, 1891. He was then about 25 years old, and he lived to an age of over 50 years.

The little African elephant now on exhibition in the park was brought from the Government Zoological Garden at Giza, Egypt, by head keeper Blackburne in 1913. At the time of her arrival she

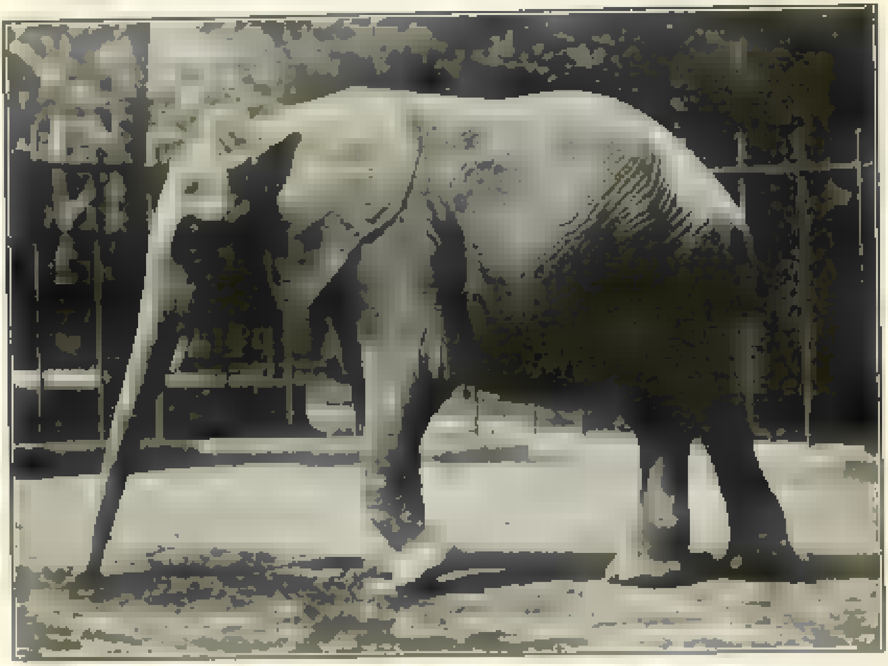
weighed 875 pounds and measured only 4 feet 3 inches in height at the shoulder. She is known as "Jumbina." She was captured in the region of the Blue Nile and is of the geographical race known as the Abyssinian elephant (*Loxodonta africana oxyotis*). In "Jumbina's" house will be seen a picture of the famous African elephant "Jumbo," probably the largest elephant ever shown in captivity, and a representative of this same Abyssinian race. Near the picture is a marked pole which shows graphically the great height of that enormous elephant—nearly 11 feet at the shoulder. There are, however, authentic records of wild African elephants of greater size than Jumbo; the highest reliable record is of one which measured 11 feet 6¼ inches.

Tusks of female elephants are much smaller and more slender than those of males, but sometimes grow to a great length. In the National Museum is a pair of tusks from a female collected by Mr. Paul J. Rainey near Mount Marsabit, British East Africa, one of which measures 5 feet 10 inches in length, and is supposed to be the record female tusk.

The tusks of elephants are the incisor teeth and are the chief source of commercial ivory. Some of the extinct elephants, as the mastodon, had tusks in the lower as well as the upper jaws. A single tusk of an East African bull elephant has been known to weigh 235 pounds, but this of course is far in excess of the normal weight even for a large animal. Heller says the average tusk weight to-day for old wild bull elephants is not more than 40 pounds for each tusk; but before the biggest males were shot off by the professional ivory hunters the average was probably about 80 pounds. The female tusk mentioned above as of extraordinary length weighs only 28 pounds.

THE TAPIRS.

Two pairs of the Brazilian tapir (*Tapirus terrestris*) are living in the Zoological Park under very different conditions. One pair, quartered near the elephants in outdoor yards with warm but unheated shelter, have withstood the winter weather of Washington since 1911. These animals came from the Zoological Gardens at Buenos Aires when about 2 years of age. They appear quite unmindful of the cold and are in perfect condition. It is not at all unusual in winter to see them out enjoying themselves in the snow when other animals, even those from temperate or colder climates, have retired to their shelters. The other pair, with quarters in the lion house, have been much longer in the park—the male since 1899. This pair has been of more than usual interest to visitors and to the management of the park for they have reared no less than nine young since 1903. Their progeny now live in zoological gardens in several American



AFRICAN ELEPHANT.

BRAZILIAN TAPIR.

MONGOLIAN WILD HORSE.

GREVY ZEBRA.

cities. The record of births from this pair is as follows: May 15, 1903, male; November 7, 1904, female; June 27, 1906, male; October 13, 1907, male; February 28, 1909, male; July 11, 1911, female; May 24, 1913, male; August 4, 1915, male; February 22, 1918, female.

Young tapirs are pretty little creatures with stripes and spots of yellowish white which gradually disappear during the first eight months after birth.

Other species of tapir are found in the forests of western South America, in Central America, and in the Malay region. The Brazilian species is especially fond of water and spends much of its time in marshy places.

THE HORSE AND HIS KINDRED.

The horse family is represented in the park by the wild Mongolian species (*Equus przewalskii*) called Przewalski's horse, and two species of zebra. There are also interesting hybrids between the zebra and horse, and the zebra and ass.

The Przewalski's horse is the only living species of truly wild horse. It inhabits the Gobi Desert region of central Asia where living specimens were captured by an expedition organized by Hagenbeck in 1900. The descendants of this stock are now exhibited in zoological gardens in many parts of the world. In his long shaggy winter coat this horse is a creature of striking appearance. On the outlying borders of the Gobi many of the horses owned by the Kirghiz tribes are apparently mixed with the blood of wild stock.

The specimen of the common East African zebra (*Equus burchelli granti*) was brought from Nairobi, British East Africa, in 1909 by Mr. A. B. Baker. He was then a young animal about 18 months old. Zebras are found over much of southern and eastern Africa and in certain localities are very abundant, living in great herds and mingling freely with various species of antelopes and other game. They are much preyed upon by the lion and are a favorite food of the natives.

Grevy's zebra (*Equus grevyi*), a considerably larger and more closely striped species than the common zebra, is confined to the more arid parts of northeastern Africa, especially Abyssinia, Somaliland, and northern British East Africa. It has a much longer and narrower head than the common zebra and is a more handsome animal. The two males in the park weigh 850 and 880 pounds. The first specimen to reach the park was presented to President Roosevelt by Emperor Menelik of Abyssinia in 1904.

Experiments in breeding the Grevy's zebra with the horse and ass have been conducted by the United States Department of Agriculture. Fine examples of each of these interesting crosses have been

deposited in the park by the department. The zebra-horse hybrid, "Juno," is an especially beautiful animal. This cross was effected by means of artificial impregnation.

THE HIPPOPOTAMUS.

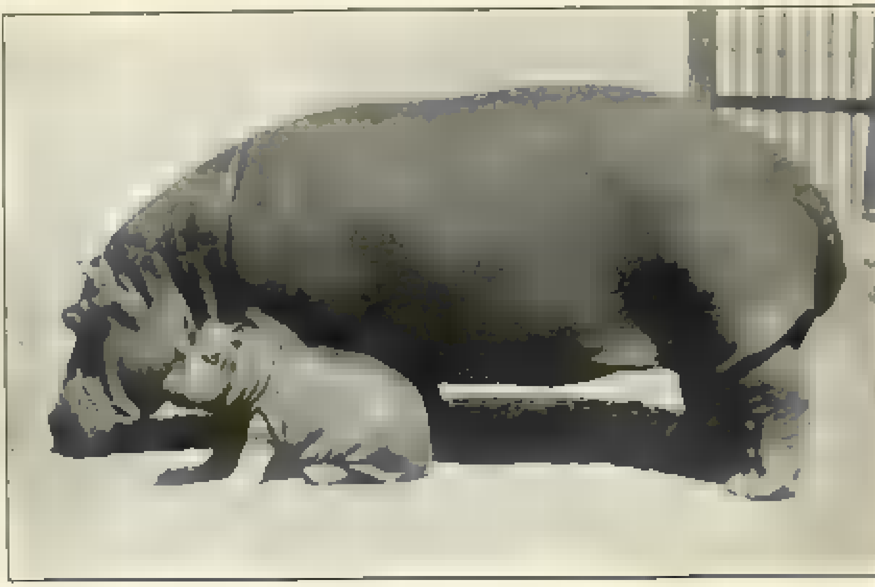
Remains of fossil hippopotamuses are found in various parts of Asia and Europe, even in England, but the existing species are confined to Africa. In addition to the several geographic races of the common species (*Hippopotamus amphibius*), a smaller kind, the pigmy hippo, is known. This latter is confined to western Africa and is very rare in collections. Hippos are essentially aquatic animals and swim with ease. It is said that they remain beneath the surface of the water for so long a time as [illegible] minutes. On several occasions the introduction of the hippopotamus into the rivers and lakes of the southern United States has been advocated with the expectation that the animal would successfully rid the waters of congested aquatic vegetation. In view of the serious depredations upon planters' crops which might well be expected, the advisability of such an experiment is questionable.

Of the hippos living in the park, the female and older animal was obtained from British East Africa in 1911. She was then about 2 years old and weighed 800 pounds. She has grown greatly since her arrival and now weighs about 3,500 pounds. She is gentle and loves attention from her keepers. The male hippo came from German East Africa in 1914 and is a much less perfectly tempered animal. He is active and remarkably agile for a beast of his great bulk and can turn and charge with great speed. A young male was born in the park May 23, 1917. He weighed about 45 pounds and was an expert swimmer at birth. The hippos are quartered in the lion house, where they have access in summer to large outdoor yards and a tank. In winter they are furnished with heated water for their bath and frequently cause great commotion by their vigorous splashing.

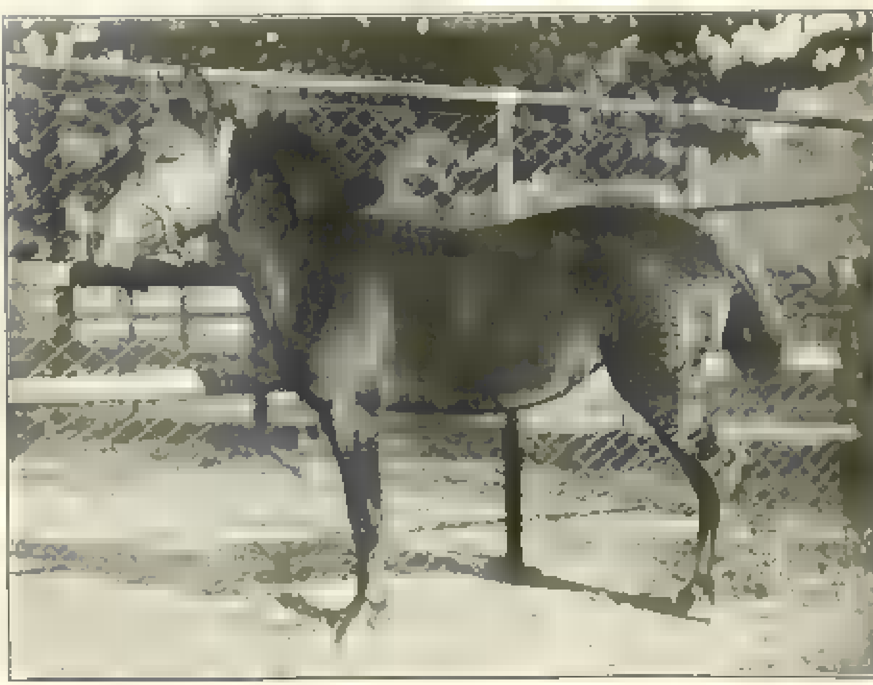
Traveling menageries usually advertise the hippo as the mighty "blood-sweating behemoth." The "blood sweat" is a curious colored secretion of the skin. Beddard thinks the description of the "behemoth" of Job much more suggestive of the elephant than of the hippopotamus.

THE WILD SWINE.

The wild boar of Europe (*Sus scrofa*) typifies the family of swine. It is presumably the ancestral form of the domestic races. A fine example is shown in a yard near the elephant house. The wart hog of Africa (*Phacochœrus æthiopicus*) is famous for his ugly appear-

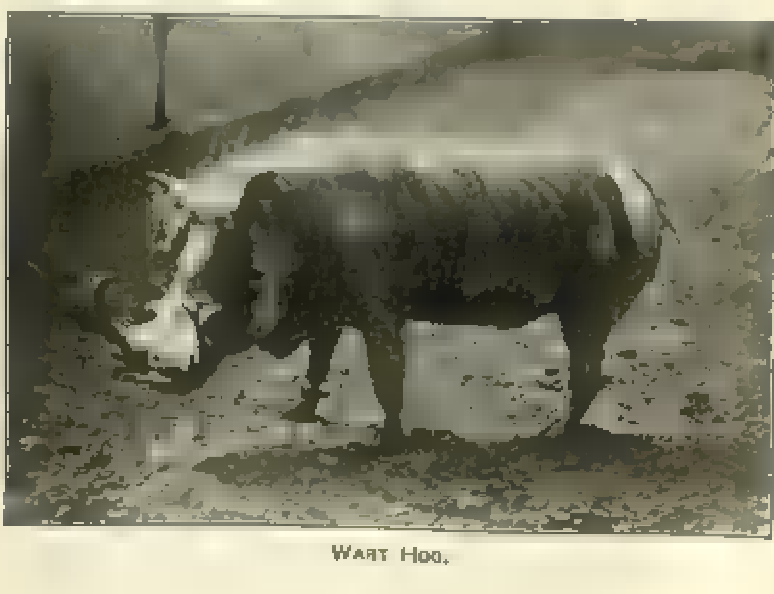


HIPPOPOTAMUS AND YOUNG.



ZEBRA-HORSE HYBRID.

LLAMA.



WART HOG.

ance and huge tusks. A fine pair of this peculiar wild pig are to be seen in quarters in the antelope house.

The American representatives of the pig family, the peccaries, are found wild from Texas southward over much of Middle and South America. Two general types are distinguished, the white-lipped and the collared peccaries. The latter ranges farther to the north than the larger white-lipped group and was formerly common in the United States along the Mexican border. Although peccaries are doubtless at times, especially when roving in large packs, dangerous beasts to encounter, the stories told of their ferocity are often greatly exaggerated. The collared peccary of Texas (*Pecari angulatus*) has frequently bred in the National Zoological Park.

THE CAMEL TRIBE.

Whether any of the wild camels of Central Asia are really native wild animals or not is a moot question. Many naturalists believe that the Bactrian or two-humped camels now found in a wild state in remote parts are merely the feral descendants of stray domestic animals, after the manner of the wild Spanish horses formerly occurring in the southwestern United States. Camels are popularly associated with hot barren deserts, but the two-humped camel (*Camelus bactrianus*) is used in great numbers on the bleak steppes of Siberia where the temperature at times is anything but moderate. Great caravans of these famous beasts of burden carry the rough felt and other products of the desert tribes and Mongolians northward to the Siberian Railway. The specimens of this species kept in the park are much more hardy than the Arabian camels.

The dromedary, or Arabian camel (*Camelus dromedarius*) is the species so much used as a pack and saddle animal in northern Africa. A drove of 75 camels of this species was introduced by the United States Government from Smyrna into the southwestern states in 1856, and others were obtained 10 years later. Escaped animals from these introductions frequented the Arizona deserts in a wild state up to about 1898, when the last survivors were killed. Both species of camels have bred in the park.

From the evidence provided by fossil remains, America was at one time inhabited by many camels and camel-like animals, which occupied the country even so far to the north as the arctic portions of Alaska. The sole remaining species are the forms of the genus *Lama* found in South America.

The wild llama, or guanaco (*Lama huanachus*) is found in herds from Ecuador to southern South America and ranges from sea level in Patagonia to high altitudes in the Andes. It differs conspicuously from the Old World camels in its small size and the absence

of humps on the back. It was early domesticated by the natives of South America and two general types or breeds have been evolved—the domestic llama, kept chiefly as a beast of burden; and the alpaca, bred for its woollike coat. The wild guanacos are of uniform coloration but the domestic llama and alpaca are variegated brown, white, and black, or of solid colors.

All of the forms of the llama breed freely in the National Zoological Park, and the young are graceful, attractive animals, much admired by visitors.

The vicuña (*Lama vicugna*) is a smaller species than the guanaco, with a distribution limited to the higher Andes of Bolivia, Ecuador, and Peru. It has never been domesticated, but the animals in the park have been gentle and do not seem to suffer from confinement in small yards. With the llama already in use and bred into different varieties, there was little reason for special effort by the natives to add this high mountain species to their list of domestic stock.

THE DEER PADDOCKS.

No less than 15 species of the deer family (Cervidæ) are usually shown in the National Zoological Park. Deer are attractive exhibition animals and with proper care do very well in captivity. It is often possible to show small breeding herds in large open paddocks where the animals present a natural and pleasing appearance.

The members of the deer family are of special interest to sportsmen, and to the average visitor are a never ceasing source of wonder on account of the annual shedding of the antlers. These antlers are present in the males of most of the species of true Cervidæ, and are well developed in the females of the caribou and reindeer. They are dropped annually after the rutting season, and during renewal are covered with the "velvet" which is later worn off when the antlers are polished by the animals' rubbing them against trees and rocks. The growth of the new antlers is astonishingly rapid and in Siberia the maral, or native elk, is kept in large numbers for the antlers alone. These are sawed off while in the velvet and shipped in great quantities to Mongolia and China where they bring good prices for medicinal purposes.

The most stately and conspicuous of the American deer is the wapiti or American elk (*Cervus canadensis*). Although less in size than the moose he is of more graceful and handsome proportions. This fine animal once ranged over much of the United States but is now restricted to a few localities where the species has been carefully preserved. The greatest numbers are to be found in the Yellowstone National Park and the surrounding country, whence numbers have in recent years been shipped into several Eastern

ARABIAN CAMELS.

RED DEER.

MULE DEER.

AXIS DEER.

PHILIPPINE DEER.

KASHMIR DEER.

BARASINGHA DEER.

States which were, years ago, inhabited by the species. The elk range in the Zoological Park is situated along the eastern border, between Rock Creek and the boundary fence. The animals breed freely in this place and are maintained in splendid condition.

Near relatives of the American elk are the Bedford, or Manchurian stag (*Cervus xanthopygus*), the Kashmir deer (*C. hanglu*), and the red deer of Europe (*C. elaphus*). These are all represented in the park by fine breeding herds. The Bedford deer and the Kashmir deer were presented to the park by the Duke of Bedford from his herds at Woburn Abbey, England. Three fawns were born to the Kashmir deer while in transit from England and while in quarantine and these have grown to be fine animals. The European red deer breed in the park.

The common white-tailed, or Virginia deer (*Odocoileus americanus*); the mule deer (*O. hemionus*) of the Rocky Mountain region; and the black-tailed deer of the Pacific coast (*O. columbianus*) all do well in the park and breeding herds are shown in large, open yards. The Virginia deer is probably the best known big game animal in the United States. It ranges, in some of its geographical forms, from New Brunswick to South America. It is greatly to be regretted that the quarantine regulations now in force against hoofed mammals from South America make it virtually impossible to import and exhibit any of the remarkable and characteristic species of deer native to that country. These are of types very different from the deer of other lands and should be shown in the park.

Among the Old World kinds none are more beautiful and attractive than the fallow deer (*Dama dama*). These deer are spotted in summer but the winter coat is of uniform color; the antlers are comparatively large and somewhat flattened or palmate. This species is a native of the Mediterranean region, but has long been introduced in western Europe where it lives in a wild or semidomestic state. Blackish and light colored varieties have been bred, and specimens of the former are usually to be seen in the park herd.

The axis deer or chital (*Axis axis*) is spotted at all seasons. It is a native of India and a closely related form is known from Ceylon. The antlers of this deer are long, slender, and of three tines—a prominent brow tine and one fork above. Another spotted oriental species shown is the hog deer (*Hyelaphus porcinus*). This is a more sturdy species than the axis but is only about 26 inches high at the shoulder.

The large group of oriental deer known as the rusine species are represented in the park by the sambar (*Rusa unicolor*) and the Luzon deer (*R. philippinus*). Numerous species of *Rusa* occur throughout southeastern Asia and on many of the East Indian Islands. Most of the larger islands of the Philippine Archipelago have their dis-

tinct species, sometimes two. The antlers are normally stout and of three tines, but in some species are very small and with elongated pedicles. A buck of the Philippine deer which has lived in the park since 1904 was presented by the late Admiral Evans. When this deer has posed long enough for the public and is satisfied to call it a day he retires to his shelter and closes the door.

The park possesses a fine herd of the barasingha, or swamp deer of India (*Rucervus duvaucelii*). This striking species thrives in the large paddocks provided for it. Its antlers are large, sweeping, and many-tined. The little Japanese deer (*Sika nippon*) also is shown.

THE ANTELOPES.

Asia and Africa are the present-day homes of a great group of bovine animals known as the antelopes. In Africa, especially, this group offers the most astonishing diversity and the species range in size from the tiny dik-dik to the giant eland. There are brilliantly colored forest species and plain colored desert forms; solitary species and others which graze in great herds. Frequently these herds are composed of animals representing a number of distinct genera. The true antelopes, like the cattle, have hollow horns which grow and are retained throughout life—as opposed to the solid, deciduous antlers of the members of the deer family.

Among the African antelopes in the park are the great, gentle-faced East Africa eland (*Taurotragus oryx livingstonii*), presented by the Duke of Bedford; the Congo harnessed antelope (*Tragelaphus gratus*), a beautifully marked species in which the males are a deep chocolate brown in color while the females and young are of a rich cinnamon rufous; the sable antelope of South Africa (*Ozanna niger*), with his long bowed horns; the gazelle-like springbuck (*Antidorcas marsupialis*); the Defassa water buck (*Kobus defassa*); and the rather spectacular and very noisy wildebeest or gnu (*Connochaetes gnu*). With the exception of the elands, which have large paddocks to the north of the elephants, all of these African species are kept in the antelope house, where they have heated quarters in winter and pleasant yards for summer range.

The Asiatic antelopes shown include the fine, large species known as the nilgai (*Boselaphus tragocamelus*) and the small black buck (*Antilope cervicapra*). Both of these species are restricted to peninsular India. The females of each are without horns and differ markedly in color from the males. The black bucks thrive in the National Zoological Park in outdoor paddocks with unheated shelter, and both species regularly breed.

The American Antelope or pronghorn (*Antilocapra americana*) belongs to a separate family. It was formerly abundant on the western plains but is now found in only a few scattered localities.

EAST AFRICAN ELANDS.

HARNESSED ANTELOPES.

WATER BUCK.

PRONG-HORN ANTELOPE.

INDIAN ANTELOPE, OR BLACK BUCK (FEMALES).

ROCKY MOUNTAIN SHEEP.

AOUDAD, OR BARBARY SHEEP.

This animal differs considerably from the true antelopes. The horns are shed annually, only the bony core persisting throughout life. The pronghorn is especially hard to keep in eastern zoological gardens and specimens are not always on exhibition in Washington. It is a matter of great satisfaction that one example was kept in the park for so long a period as five years.

GOATS AND SHEEP.

Goats and sheep are native to many sections of the northern parts of both hemispheres, and many and diverse wild species are known. They are closely related, and forms of each have long been domesticated and bred along lines of most utility. Specimens of one of these primitive domestic breeds, the Circassian goat, are kept in the park.

The tahr (*Hemitragus jemlahicus*) of the Himalayas and the aoudad, or Barbary sheep (*Ammotragus lervia*) of northern Africa, are species which connect in many features the true goats with the sheep and make it difficult to draw a sharp distinction between the groups. The male tahr is an animal of striking appearance, with his heavy collar and mane of long, shaggy hair reaching to his knees. He is an animal of the forested mountains and an exceptional climber and jumper. The aoudad is another animal that attracts great attention in the Zoo. Although lacking the regular beard of the goat, he has extraordinarily developed hair on the neck and fore limbs, and an upright mane extending to near the middle of his back. The aoudad is also at home on the steep slopes that are included within his paddocks.

The Rocky Mountain sheep, or bighorn, which is known in some of its geographical forms in western North America from Alaska to Mexico is well represented in the park by five specimens of the typical form (*Ovis canadensis*) received from the Dominion parks branch of the Canadian Government. These sheep came from the protected area included within the Rocky Mountains Park and were shipped from Banff, Alberta. The Arizona race (*O. c. gaillardi*) is also shown.

An interesting form of the domestic sheep known as the Barbados sheep, but which originated in Africa, is remarkable for its peculiar brownish markings and short hair. The flock shown has all the appearance of a wild species and was received from the United States Department of Agriculture.

BISON, YAK, AND THEIR ALLIES.

The herd of American Bison (*Bison bison*) maintained in the National Zoological Park has been brought together from various

sources. It is now kept at approximately 17 head and the surplus stock is exchanged to other parks and bison reservations. There are now many places where bison herds are kept and carefully protected and bred so that all danger of the extinction of this famous American ruminant is past. The number of animals is increasing yearly under the direction of the American and Canadian Governments and the American Bison Society; new herds and reservations to accomodate the surplus animals have been created.

The first bison to be placed in the National Zoological Park herd were a pair received from E. G. Blackford in 1888, when the collection was kept at the Smithsonian grounds. Animals have since been added from outside sources as follows: Dr. V. T. McGillicuddy, 1889, 4; M. Pablo, 1897, 3; C. J. Jones, 1901, 1; Cody and Bailey, 1904, 7; Dr. C. French, 1907, 1; and the Blue Mountain Forest Association, 1907, 3. All danger of too free interbreeding has thus been eliminated and arrangements have recently been made to receive some young bulls from the Yellowstone National Park. Up to 1918, 83 calves had been born in the park herd. There appears to be no restricted season for calving, as births are noted in the park records for every month in the year except February and December. May ranks first with 11 births, April and November second, with 5 each, and January, March, and July are lowest with a single birth credited to each. The bison range is located near the Connecticut Avenue entrance, on the western side of the park.

The yak (*Poëphagus grunniens*) is found in a wild state in the very high mountains of central Asia, in Ladak, Tibet, and Kan-su, where it lives at altitudes varying from 14,000 to 20,000 feet. The color of the wild stock is a blackish brown. Tame, semiwild, and feral herds ranging northward into the Altai Mountains at much lower altitudes, even to the Siberian slopes of the Little Altai, are of mixed colors, black, brown, gray, and white. Both sexes normally have horns; those of the male ofttimes are of great length. The natives of central Asia say that the yak is not successfully kept below 4,000 feet in that region. The animals in the Zoological Park, at what is practically sea level, do not seem to suffer from the low altitude, and frequently breed.

An example of the little buffalo of Celebes, known as the anoa (*Anoa depressicornis*), is one of the prize exhibits of the park. The animal is very rare in collections and is not often seen alive. Our specimen, a fine bull, has been living in his quarters at the antelope house since 1905, a record of which his keepers may well be proud. He is a snappy, pugnacious animal, quick with his feet and temper, although the smallest of all the buffalo species. The calves of *Anoa* are sometimes of a beautiful golden brown and some of the females retain this color throughout life; but the males are usually blackish

AMERICAN BISON.

YAK.

MANDRILL.

PATAS MONKEY.

CHIMPANZEE.

like the one exhibited. The straight, sharply-pointed horns are much in favor with East Indian sailors for use as marlinspikes.

The zebu (*Bos indicus*), a domestic variety much bred in parts of Asia and Africa, is shown in paddocks near the west gate.

THE PRIMATES.

The order of mammals known as the Primates includes the lemurs, monkeys, apes, and man. The lemurs are mostly nocturnal animals and are, so far as living forms are concerned, not closely related to the other Primates. In some species the tail is very long; in others it is wanting entirely. At the present age the lemurs are confined to Africa, the oriental region, and to Madagascar and neighboring islands. Many of the species are confined to the latter region.

The other Primates are usually divided into several families. The principal groups are the marmosets, small species often of brilliant coloration and silky coat, confined to tropical America; the remaining American monkeys, of great variety in size and characteristics and of an uncertain number of families; the Old World monkeys, all rather closely related as compared with the great diversity shown by the American species; the anthropoid apes, including the gorilla, orang-utan, chimpanzee, and gibbon; and finally man.

While the majority of the Primates kept in the park are exhibited in the monkey house, several outdoor yards and shelters are provided for such species as endure our winters without heated quarters, and the chimpanzee makes his winter home in a specially prepared corner of the lion house.

THE CHIMPANZEE (*Pan troglodytes*).

No animal in the park attracts so much attention from visitors as "Soko," the chimpanzee. "Soko" reached the park in September, 1915, from the forests of the French Congo. He was then about 3½ years old and weighed only 38 pounds. During the autumn of 1916, or when about 4½ years old he lost his milk teeth and since the permanent teeth have developed his growth has been much more rapid than before. On September 1, 1918, he weighed 85 pounds. He has been taught by his keepers to take his formal meals seated at a table; and after his napkin has been adjusted he scans the menu, writes his order, and rings his bell for service. Sliced bananas, rice pudding, and other foods are eaten with fork and spoon in a conventional manner, much to the joy of the children who crowd about his cage. He pours his own milk from the bottle and has never but once overfilled his glass, since which mishap he has always exercised particular care not to waste this food.

"Soko" does all sorts of unexpected tricks and is a creature of extreme moods. At times he is very grave and serious, and again, especially if he has an appreciative audience, he is bubbling over with the joy of life and spins round and round on his back and shoulders or turns somersaults repeatedly. During the warmer months he occupies pleasant quarters out-of-doors where he has a dry and cosy sleeping room with a large cage; and at that season he enjoys daily walks about the grounds and many rides on the watchman's bicycle.

OLD WORLD MONKEYS.

With few exceptions the Old World monkeys are all exhibited in the building known as the monkey house. The exceptions are hardy species which seem unmindful of our coldest winter weather and thrive in unheated outdoor cages, where they are provided of course with snug and comfortable sleeping quarters. These "fresh air" monkeys include the rhesus monkey (*Macaca rhesus*), a social species of northern India; the brown macaque (*Macaca speciosa*), of Upper Burma and Cochin China, in which the tail is nearly obsolete; the Japanese monkey (*Macaca fuscata*), a long-furred, naked-face, short-tailed species; and the chacma (*Papio porcarius*), a South African baboon of large size and great strength. A full grown male of this powerful baboon is said to be a match for a leopard; and as the animals usually live in troops, so great a number as 100 being sometimes associated in this manner, they at times are responsible for great depredations to crops, and have been known to kill lambs and other stock.

In the monkey house and the annexed outdoor yards for summer use are shown a variety of the Old World species. A number of forms of macaques, related to those mentioned above, are usually here. These include the bonnet monkey (*Macaca sinica*), a native of southern India; the pig-tailed monkey (*M. nemestrina*) of the Malay region; the Moor macaque (*Cynopithecus maurus*) from Celebes; and others. The mangabeys, a tropical African group of long-tailed, forest-loving monkeys is represented by the sooty mangabey (*Cercocebus fuliginosus*), an obscurely colored but very active species.

The guenons form the largest group of the Primates and exhibit remarkable diversity in coloration and color pattern. They are attractive and very interesting monkeys with slender bodies and long limbs and tails. Some of the species are oddly and brilliantly colored. The group includes about 80 forms and is native to Africa; but two species (the mona and the green guenon) have been introduced into the West Indies and are perfectly established on some of the islands. Attractive species of this genus shown in the monkey

ARABIAN BABOON.

PIG-TAILED MACAQUE AND YOUNG.

of them are strikingly colored. The mongoose lemur (*Lemur mongos*) is a noisy, gregarious species, noted for its agility in trees. In addition to this species, the black lemur (*L. macaco*) is shown in the monkey house.

THE EDENTATA.

This group of so-called "toothless" mammals contains, in addition to some peculiar Old World types of doubtful affinity, the American sloths, anteaters, and armadillos. The teeth are very imperfect in structure and in some forms are wholly absent. The armadillo, the only edentate regularly exhibited in the zoological park, has numerous functional teeth, but these are without a real covering of enamel. Sloths and anteaters usually do not live well in captivity and are shown in the collection only occasionally, as specimens can be secured.

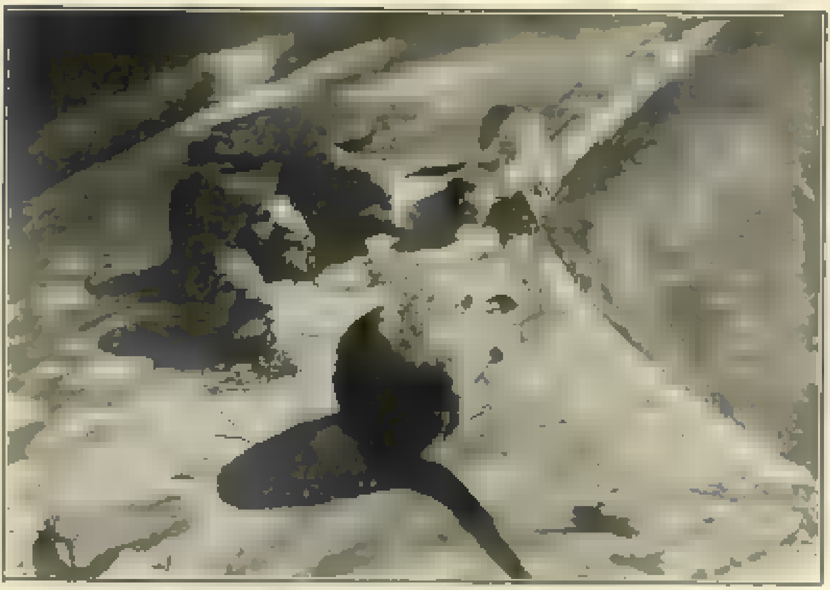
The hairy armadillo (*Euphractus villosus*) comes from South America. Numerous other species and genera are found in this region and one (*Dasypus novemcinctus*) ranges commonly north into southern Texas. The shell-like covering of the back of this form is much used for making baskets for the tourist trade. Armadillos are curious animals and are surprisingly quick and nimble on their feet. Some species are able to roll up in a ball; the horny carapace then gives them protection from their enemies.

THE GNAWING MAMMALS.

Among the gnawing mammals are included two very distinct orders—the Rodentia and the Lagomorpha. The latter order is made up of the hares, rabbits, and pikas, while all the other existing rodent-like forms are members of the order Rodentia. The vast majority of rodents are small creatures, like the mice, rats, and squirrels; but the order includes some very sizable living animals—the porcupine, beaver, and capybara, while an extinct South American member of the group was as large as a hippopotamus. The most characteristic features of the Rodentia are the complete absence of canine teeth and the great development of the incisors which, owing to their persistant growth and the presence of hard enamel chiefly on the anterior surface are worn by use to a chisel-like edge. There is always a considerable space on the jaw between these cutting teeth and the molariform grinders.

Until some special means for the exhibition of living examples of the smaller rodents and lagomorphs can be devised, the collection must be mainly restricted to the larger forms. The common gray squirrel, the red squirrel, and the cottontail rabbit roam wild within the borders of the park. Among the gray squirrels will be seen nu-

WORK OF BEAVERS IN NATIONAL ZOOLOGICAL PARK.



COYPUS.

CRESTED PORCUPINE.

merous black or blackish examples. These are descendents of black squirrel stock introduced in the park a number of years ago from southern Ontario. Other members of the squirrel family shown are the Abert's squirrel (*Sciurus aberti*) from Arizona, the prairie dog (*Cynomys ludovicianus*), and various species of ground squirrels and marmots. The prairie dogs have an inclosed area near the eland yards where they live the social village life so characteristic of the species. Numbers of young are born and reared each year. During the coldest winter weather the prairie dogs hibernate, but in nice weather they are always to be seen about the "dog town."

Two aquatic rodents, the American beaver (*Castor canadensis*) and the coypu (*Myocastor coypus*) of South America enjoy the running stream above the sea lion pool. The beavers have an extensive yard and have dammed the stream in true beaver fashion so that the resulting lake offers them the most natural surroundings. They are best seen in the late afternoon. The coypu, or nutria, is thoroughly at home in the water, and the teats of the female are placed high on the side of the back so that the young are able to nurse without diving. The fur is valuable for many purposes but is chiefly cut and used in the manufacture of hats. As many as 500,000 skins have been exported from South America within a single year.

The European porcupine (*Hystrix cristata*) is a splendid species whose quills are far longer than those of the American porcupines.

Among the attractive rodents found only in tropical America are the families Caviidæ, Dasyproctidæ, and Chinchillidæ. Many species are peculiarly adapted to zoological park life, are showy animals, and breed regularly in captivity. The guinea pig (*Cavia porcellus*), so familiar to children, is bred in large numbers. The wild guinea pig of Peru, a grayish species, is also on exhibition. A larger species, the Patagonian cavy (*Dolichotis patagonica*), a peculiar rough-haired animal with something the appearance of a big rabbit, is shown in the antelope house. The paca (*Cuniculus paca*), one of the larger rodents, has a brown body well marked with whitish spots. He is related to the agouti (*Dasyprocta*) of which a number of species are regularly kept. Some of the species of agouti are brilliantly marked; a most striking species is the hairy-rumped agouti (*D. prymnolopha*). Agoutis range north into Mexico and on several of the West Indian Islands. They are hunted with dogs by the natives, and are said to be almost as cunning as a fox. The viscacha (*Lagostomus maximus*) is related to the famous chinchilla. It has some of the habits of the prairie dog and lives in villages in open country, but the towns do not approach in size those of the North American animal.

The mountain beaver, or sewellel (*Aplodontia rufa*) is a peculiar burrowing rodent of the Pacific coast region of North America. It

much resembles the muskrat in external appearance, but has a very short tail, scarcely an inch in length; and is not closely related to the other existing members of the order.

The capybara (*Hydrochaerus hydrochaeris*) is a native of South America, north to Panama. This species is very fond of marshy tracts and is an expert swimmer. The specimen now on exhibition was received from Venezuela. Capybaras sometimes grow to more than 4 feet in length; they are thick-set animals and although easily the largest of the existing rodents are gentle, inoffensive, and easily tamed.

THE CARNIVOROUS MAMMALS.

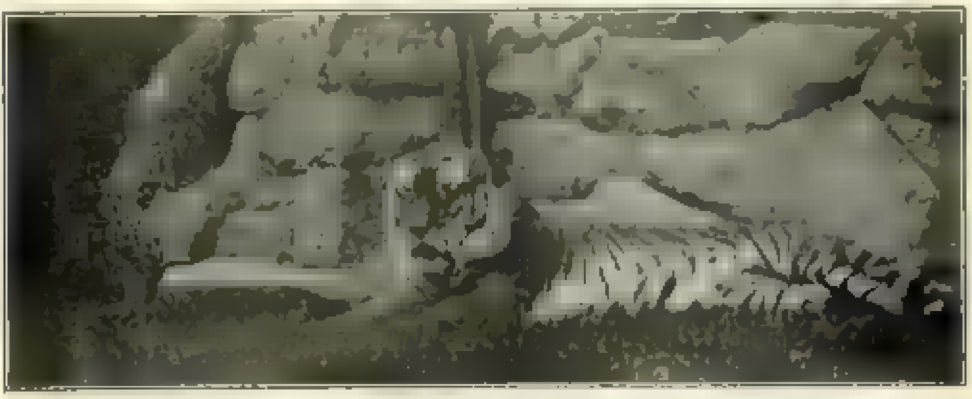
Two distinct orders of this group are now recognized by mammalogists. The Carnivora proper, or Fissipedia, include the families of cats, civets, hyenas, dogs, raccoons, weasels, and bears, with their allies. The order Pinnipedia is comprised of the seals, sea lions, and walrus. While there is immense variety in the dentition of carnivorous mammals, as a rule the teeth are highly developed for the process of tearing and cutting flesh or the crushing of bone. Some species are far from "carnivorous," and subsist chiefly upon fruits and insects. The black and brown bears are good examples of this latter type, but most carnivores do at times eat more or less of vegetable food. Some of the smaller species are largely insectivorous.

The largest of living carnivores is the great brown bear of Kodiak Island, Alaska; the smallest the least weasel of the boreal regions of both continents.

The Pinnipedia are readily divided into groups typified by the hair seals or harbor seals; the sea lions; and the walrus. The hair seals have no external ears and the hind limbs are so placed and modified as to be useless for walking on land. The feet, or hind "flippers," protrude backward and are used in the nature of a tail in swimming. The common harbor seals of both coasts belong to this group. The sea lions, or sea bears, have external ears, and the hind limbs are functional for walking on land. This group includes the famous fur seal as well as the species of sea lions. Peculiarities of the skeleton point to a very ancient separation of these two groups of seals, and they are not so closely related as would appear from their external appearance and habits.

THE CATS.

Specimens of the larger members of the cat tribe are usually kept in all menageries and are favorite animals with the public. The collection in the National Zoological Park includes beautiful examples of many of the most interesting and showy species. The larger kinds are shown in the lion house.



BENGAL TIGER.

LION.

AFRICAN CHEETAH.

AFRICAN LEOPARD.

The African lion (*Felis leo*) ranks foremost in popular interest. The adult male is a magnificent beast with massive head, a full mane, and a long tufted tail; he presents a most imposing appearance. Lions thrive in captivity and develop much finer manes of softer, more luxuriant hair, on the neck and shoulders than is usual in wild animals. Lions brought from the high and comparatively dry plateaus of East Africa develop much darker coats in the Zoological Park than in a natural state. This is supposed to be due to the more humid atmosphere of Washington. The mane of the lion is not fully developed until the animal has reached a very mature age and the numerous "adult" lions without manes shot by sportsmen prove to be in reality fully grown but immature animals. In the series of over 100 lions preserved in the National Museum the full-sized but maneless males are invariably the younger ones as shown by the condition of the sutures of the skull and the condition of the teeth. The mane grows much more rapidly in park specimens and appears fully developed at an age when wild lions would still be "maneless." Numerous geographical races of the lion are known, and the range of the animal extends into western India. Within historic times the species was wild in southeastern Europe.

The tiger, the lion's rival in size, strength, and popular interest, is an inhabitant of Asia, where it ranges through its various forms from southern Siberia to Java and Bali, and westward to Persia. It is absent from the greater part of the highlands of the central parts of the continent but has been killed so far north as Sakhalin Island on the coast and the northern slopes of the Altai in central southern Siberia. It is best known from Korea and Manchuria, the Amoy region of eastern China, Malaya, and India, each region furnishing a special type. The Bengal tiger (*Felis tigris*) is the best known form in menageries. It has a short coat and is a very inferior animal to the splendid Manchurian tiger of the north (*Felis tigris longipilis*). The Manchurian tiger is common in parts of Korea where it is usually hunted on the snow in winter. Both the Bengal and Manchurian tigers are represented in the Zoological Park collection of the great cats, and the numerous points of difference between these two forms are readily seen. The most beautiful of all the tigers, the Amoy species, has never been shown; although skins regularly reach the market, living specimens are rarely obtainable. The same may be said of the very distinct Persian form. The Malay and Sumatra tigers are frequently seen in zoological gardens and specimens of the former lived for many years in the National Zoological Park.

The leopard (*Felis pardus*) of Asia and Africa and the jaguar (*Felis onca*) of America are spotted cats with many superficial points of resemblance. The leopard is a less stocky animal than the jaguar though he exceeds in size many of the smaller specimens of the American species. Like the lion and the tiger the leopard is divided into several subspecies or geographical races. Both the African and Asiatic forms are kept in the park. The jaguar ranges from Argentina northward to Mexico, and is sometimes killed in the wilder parts of Texas and New Mexico. Unlike the puma, or mountain lion, it is at times very destructive to cattle. The smallest jaguars come from northern South America and the largest form inhabits Paraguay and southern Brazil. The great difference in size between specimens from these two regions is remarkable. Skulls of adult male specimens of the Paraguay jaguar exceed in measurements the skull of the largest Korean tigress recorded.

The puma, known in the Western States as the mountain lion and in the south as the panther, has an extensive distribution from British Columbia to Patagonia. It was formerly common in the Eastern States, but is now exterminated over much of its original range. In parts of Florida and especially in the canebrake regions of Louisiana, panthers are still found. In the Bear Lake cane of northeastern Louisiana the animal was almost common a few years ago and doubtless is frequently found to this day. The mountain lion of the Rockies (*Felis hippolestes*) and the paler colored form from Arizona (*Felis azteca*) are both exhibited in the park. In parts of the West and Southwest the mountain lion is still found in numbers, and in particular localities is so destructive to colts that it is almost impossible to raise horses on the open range. There are several authentic instances of the mountain lion's attacking man without the slightest provocation; but considering the wide distribution of the animal and its comparative abundance, these must be considered exceptional traits of habit.

The ocelot (*Felis pardalis*) is a smaller spotted and blotched American cat, common in the Tropics and regularly found in southeastern Texas. It is a handsome species which varies greatly in color and markings. The Canada lynx (*Lynx canadensis*) is a larger, tufted-eared relative of the common bobcat, or wildcat, of the United States. It is found over much of the wooded parts of British America and Alaska and into the Northern States and Rocky Mountain region of the West. It is much sought by the trapper and during the periodical abundance of the northern hare becomes very plentiful, so that large numbers are captured.

The bay lynx, or bobcat (*Lynx ruffus*), is the wildcat commonly found in unsettled portions of the United States. Like other species of wide distribution it is divisible into numerous geographical forms.

One of the handsomest of these is a richly colored race from the humid coast region of the Northwestern States.

The cheetah, known also as the "hunting leopard," is sometimes trained to hunt the antelope and other game. Long limbed and slender, with high rounded head, and with claws less retractile than in the other cats, he has many points of resemblance with the dog; this resemblance is not confined to external appearance but is found also in the muscles. A pair of African cheetahs (*Acinonyx jubatus*) was brought over in 1913 by the head keeper of the park from the Government Zoological Garden, Giza, Egypt. They have developed splendidly here and may be considered one of the most important exhibits.

CIVETS AND HYENAS.

The civet cats and their allies, the mongooses, genets, and palm civets comprise the family Viverridæ. They are of diverse types and are native to the Old World, but one species of mongoose has been introduced in some of the West Indian Islands where it has nearly exterminated many of the native species of birds. Regulations against the introduction of this pest into the United States are rigidly enforced.

The African civet (*Viverra civetta*), a handsome spotted species of comparatively large size, is shown in the antelope house. Another attractive member of the Viverridæ is the genet (*Genetta genetta*) of southwestern Europe; a specimen of this elegant species may be seen in the small mammal collection installed in the north end of the monkey house. Numerous related forms occur in Africa and southern Asia.

The spotted hyena (*Crocuta crocuta*) is the commonest African species of the family Hyænidæ. He is a large, powerful brute with jaws and teeth specially developed for crushing bones. The specimen kept in the lion house is a great pet and is excited to supreme content by a little attention. Unlike the great cats he pays not the slightest attention to bones in the meat fed to him but crushes even the largest as easily and rapidly as if he were eating much softer food. A smaller species, the striped hyena, inhabits India and northern Africa, and a much rarer kind, the brown hyena or "strand wolf" (*Hyæna brunnea*), is confined to parts of Africa. A specimen of this latter animal was added to the park collection in 1917. It is the first specimen of the species ever shown in the National Zoological Park, and very few have ever been exhibited in America. Hyenas are essentially carrion eaters and are largely nocturnal in habits.

THE DOG FAMILY.

This interesting group of mammals includes the dog, wolf, fox, jackal, and their numerous relatives. It is one of the best-known

families in a popular way, but the exact limits of the genera and species are matters not yet thoroughly worked out by any zoologist.

The true wolves were formerly abundant animals over much of the Northern Hemisphere, and, although exterminated by man in many regions, still persist in numbers in some well-inhabited areas. Although long since gone from the British Islands, they are found to this day in numerous parts of continental Europe and are abundant in the less settled portions of central Asia. In North America wolves formerly roamed in large packs over the great game fields and were especially numerous throughout the bison country. The northern "timber wolf" and the "buffalo wolf" of the great plains are powerful beasts and are able to take down our largest animals. The wolves of the Southern States are of less bulk and some species are barely larger than the coyote.

The wolf of the northern Rocky Mountain States (*Canis nubilus*) varies greatly in color, as usual with the American species. Among the specimens in the park are some of the typical "gray wolves" and some very dark, almost blackish examples—the latter from the Yellowstone National Park. Many young wolves of this species have been reared in the park.

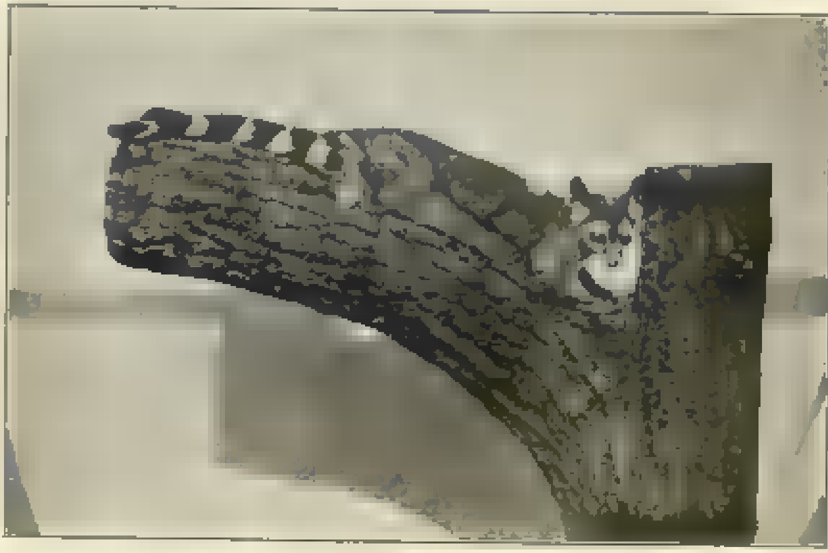
Two species of the smaller wolves from the Southern States are shown. The reddish form from Oklahoma and Texas (*Canis frustror*) resembles very much some of the species of coyotes, but his skull and teeth show him to be one of the true wolves. The black wolf of the swamps and forests of the Southeastern States (*Canis floridanus*) is represented by a splendid example from Arkansas. It is perhaps doubtful if this is the same species as the wolf of Florida, but until more is known of the small wolves of Louisiana, Arkansas, and east Texas, the specimen seems best referred to *floridanus*. While the average coloration of these southern wolves is very dark, many examples are by no means so black as the one exhibited.

The coyote of the northern plains (*Canis latrans*) is a large species approximating some of the smaller wolves in size. It ranges east to Wisconsin and western Indiana, where it is frequently confounded with the timber wolf; old hunters and trappers often fail to distinguish between the animals. In some localities it is called the brush wolf by those who recognize the difference between it and its larger and more powerful relative. Numerous other species and subspecies of the coyote are found in the Western States and in Mexico. The coyote is structurally closer to the Old World jackal than to the big wolves, and takes the place of the jackal in the American fauna.

The red fox (*Vulpes fulva*) is very common in parts of the North, but is rare in many of the Southern States. In the boreal regions of Canada and the northern United States it takes on a splendid

PLAINS WOLF.

MOUNTAIN LION.



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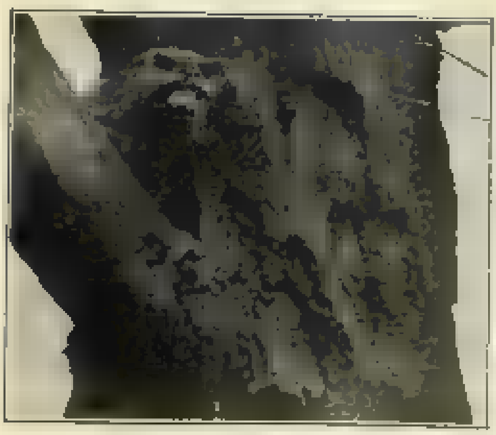


RACCOON.

FLORIDA OTTER.

coat and the fur is of considerable value. The cross fox and the black or silver fox are color phases of this species and examples of each are sometimes found in litters of red foxes. Both phases occur most frequently in definite geographic areas, however, and in some western localities the cross fox coloration is the common condition. Silver foxes are now bred in confinement and the skins frequently bring enormous prices in the fur market.

The swift, or kit fox (*Vulpes velox*) is an inhabitant of the open areas of the West and is found in many of the most arid deserts. A number of species and races are recognized by mammalogists. The fur has no real value.

The common gray fox abounds in many parts of the United States and Middle America. Unlike the red fox it is a good climber and if pursued by dogs readily takes to trees. The common eastern species (*Urocyon cinereoargenteus*) maintains itself in well-settled communities and is sometimes known by the misnomer of "silver-gray fox." In localities where it is not often taken, the capture of a specimen frequently excites the trapper to the belief that he has a specimen of the real prized and valuable silver fox. The genuine silver fox, mentioned above as a color phase of the red fox, is chiefly black, with more or less white hair mixed in the pelage; whereas the gray fox is always gray and rufous, with a blackish stripe along the upper surface of the tail. The fur of the gray fox is comparatively short and coarse, but is of real beauty and is considerably used by the trade. Its value is much less than the fur of the red fox.

The arctic fox (*Alopex lagopus*) is circumpolar in distribution and is much prized for its fur. In the boreal regions the animals are clear white in winter, though the summer coat is of a bluish brown. On some of the islands of Alaska the animals are all of the "blue fox" type and the white pelage is unknown.

The park possesses fine examples of the Eskimo dog, the descendants of the animals which accompanied Admiral Peary to the North Pole. Those now here are the grandsons and granddaughters of the original famous animals. It is greatly to be hoped that this stock can be perpetuated. The Eskimo dog is a variety of the common domestic animal (*Canis familiaris*) and, contrary to general belief, apparently is not a direct and scarcely modified descendant of the wolf now found wild in the northern regions. Examination of dozens of skulls of dogs from the ancient Eskimo dwelling sites of northeastern Siberia and from more recent Eskimo tribes fails to disclose any more wolf-like characteristics in the bones or teeth than are found in all large domestic dogs. The primitive Eskimo dog skulls are almost counterparts in all characters of the dog skulls found in ancient Egyptian burials and in the pre-Columbian graves of Peru. Domestic dogs have the general wolf type of skull and

teeth without admixture of characters derived from jackal, coyote, or any South American member of the dog family; but the animal is of very ancient origin and its actual wolf-like ancestor is not for a certainty known.

Another very interesting dog is the dingo (*Canis dingo*) of Australia. It is found in a wild state, and also, it is said, in a semidomesticated state among the natives of that country. It has been generally believed that the dingo was introduced by man into Australia at some early time but there is some evidence, furnished by fossil remains, that it existed there with some of the extinct marsupials at a period earlier than man is surely known in that region. In color the dingo is usually reddish or rufous-tawny, although individuals lighter or darker in color than the average specimens are known to occur in an apparently wild state. Whatever the true origin of the dingo it is certainly as truly a wild animal in Australia in modern times as any of the native marsupials or the rat-like rodents.

RACCOONS AND THEIR ALLIES.

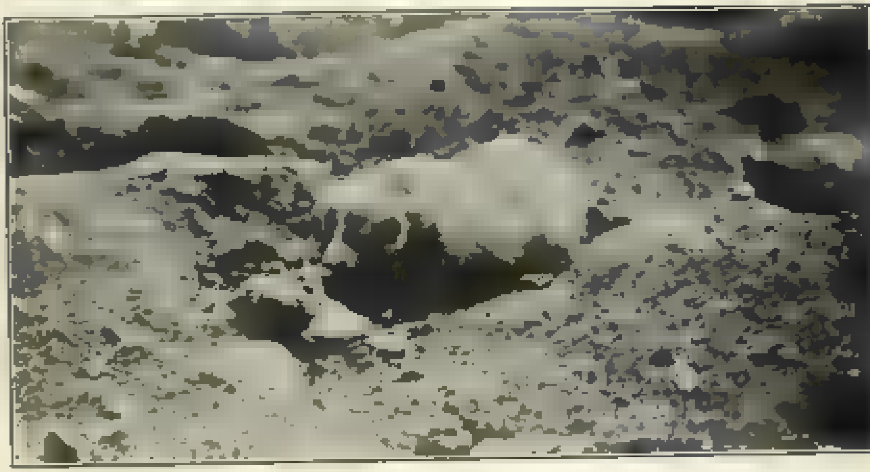
The common raccoon (*Procyon lotor*) has a special yard near the elephant houses, with a fine tree in which the animals of the colony may be seen sunning themselves in the topmost branches. South American representatives of the coon family, the kinkajou (*Potos flavus*) and the coati-mundi (*Nasua narica*) are also kept in the park. Both of these animals occur northward throughout much of Central America and Mexico, and the coati-mundi has been captured in southern Arizona.

The cacomistle (*Bassariscus astutus*) is a beautiful little animal often called the "ring-tailed cat," "coon cat," or "civet." It is common along the Pacific coast of the United States and southward into the Tropics. It has many structural characters of the dogs and although usually classified with the raccoons has been made the type of a distinct family. The fur at times becomes fashionable and many skins are placed on the market.

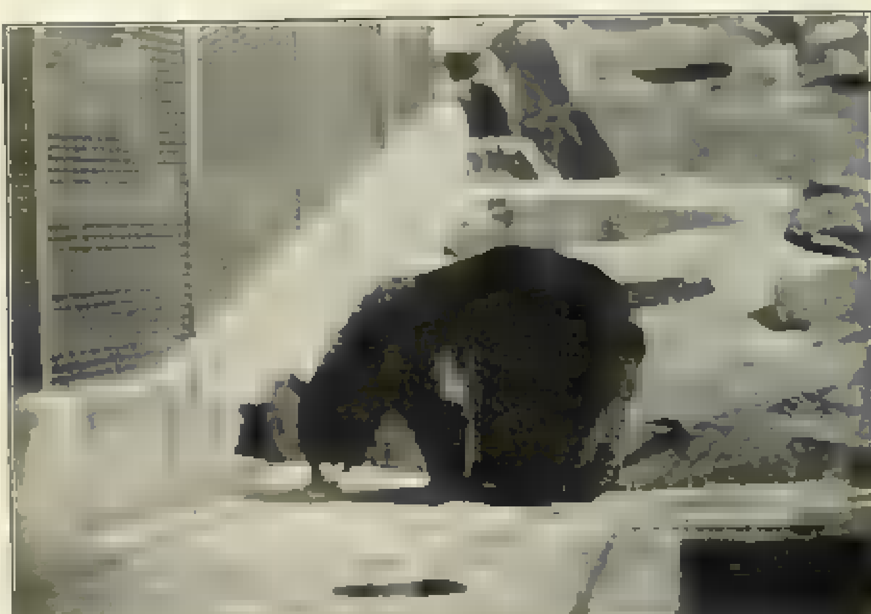
THE WEASEL FAMILY.

This group of highly bloodthirsty mammals includes such diverse types as the weasel, badger, skunk, marten, and otter. The family has an extensive distribution and species are found in most parts of the globe with the exception of Australia and Madagascar.

The American badgers (*Taxidea taxus*) have a fine yard in the park where they can usually be seen in their characteristic occupation of digging in the soil. So active are they in this work that the dirt within the inclosure is constantly turned over and always presents the appearance of a newly spaded garden. The European



AMERICAN BADGER.



GLACIER BEAR, OR BLUE BEAR.

ALASKA PENINSULA BROWN BEAR.

badgers (*Meles meles*) on the contrary are rarely seen, as they spend almost the entire day asleep under the straw in a corner of their quarters.

The common skunk of the Eastern States (*Mephitis nigra*); the marten (*Martes americana*); the fisher (*Martes pennanti*), and the mink (*Mustela vison*) are all American species which are essentially nocturnal and attract little attention in their cages from visitors to the park. The neotropical tayra (*Tayra barbara*) on the contrary is a friendly, active animal always ready to show himself to visitors.

The otter pens, along the stream above the beaver and sea lion pools, offer an attractive show of the home life of animals. Here a pair of American otters (*Lutra canadensis*) have reared their young and the mother with her family can be seen. Otters are very intelligent and playful animals and may easily be made attractive pets. Moreover, since it is practicable to rear them in captivity the breeding of otters may be made a very pleasant and profitable occupation as the skins command a fine price in the fur market.

THE BEAR DENS.

The park maintains a splendid collection of bears and few animals attract so much attention from the public as do these interesting creatures. The dens are conveniently and pleasantly located on the west side of the main highway through the park where the animals have ideal conditions for comfort and health.

The polar bears (*Thalarctos maritimus*) are confined to the arctic regions. On the Atlantic coast of America they formerly occurred regularly south to Labrador. White at all seasons, active in the cages and pool, and expert swimmers, the polar bears are great favorites in the park. Contrary to general belief the polar bears do not particularly suffer from the summer heat of Washington. It is to be remembered that there are many warm days in summer in their native home and that during this season the bears commonly go ashore and subsist for periods almost wholly upon a vegetable diet. During most of the remainder of the year the food of the polar bear consists mainly of the flesh of seals. A polar bear in the park at one time weighed 760 pounds.

The European brown bear (*Ursus arctos*) is the bear usually seen accompanying itinerant street exhibitions. It naturally stands erect on its hind feet much more than do the other bears and is, consequently, much more readily trained for such purposes.

The great and confusing variety of bears found in northwestern America has puzzled naturalists since the first discovery of those huge beasts. Some of the brown bears of Alaska, notably those of the Alaskan Peninsula and Kodiak Island, are the largest of all

living species and appear to be intimately related to the brown bears of eastern Asia and to the extinct cave bears of Europe. Several species of the great Alaskan brown bears are shown in the park. One kept for several years weighed at one time 1,160 pounds.

There are splendid examples of the Kodiak bear (*Ursus middendorffi*); the Peninsula bear (*U. gyas*); the Yakutat bear (*U. dalli*), and Kidder's bear (*U. kidderi*) of Cook Inlet.

The grizzly bear (*Ursus horribilis*) is perhaps the most celebrated of all the bears and has the greatest reputation for strength and ferocity. In the early days of the West the grizzly was very plentiful, and no story of adventure in that region was complete unless it introduced the "silver tip" at some point in the tale. Nowadays grizzly bears are rare or completely exterminated over most of their former range in the United States, but are still found plentifully in the Yellowstone National Park, from which place most of our specimens come. In the Rocky Mountains of Canada, and particularly in British Columbia, grizzly bears are commonly found. Numerous species and subspecies of grizzlies are now recognized.

The common black bear of North America (*Ursus americanus*) has a very extensive distribution from Alaska to Florida; a number of geographical races are recognized within this area. This animal has persistently held its own in some of the more settled States, and, like the white-tailed deer, with proper protection is in little danger of extermination. The cinnamon bear, a color phase of the black bear, is of most frequent occurrence in certain parts of the West where a geographical race of the common bear is recognized as *Ursus americanus cinnamomum*. A fine pair captured in the Yellowstone National Park is exhibited. Their mother, which was received with them, was black.

One of the rarest of all the bears is the glacier bear, or blue bear (*Ursus emmonsii*) of the Mount St. Elias Alps, Alaska. It is somewhat smaller than the geographical race of the common black bear found in the same general region (*Ursus americanus perniger*) and has a beautiful coat of a blue-gray color. The first living specimen of this interesting American mammal ever exhibited in any zoological garden was received at the National Zoological Park in 1917 as a gift from Mr. Victor J. Evans, of Washington, District of Columbia, who secured it from a resident of Yakutat, Alaska. It was captured as a small cub by Indians about the middle of May, 1910, at the head of Disenchantment Bay. The only specimens ever received before this time were a few skins, mostly obtained by fur traders, and several skulls which have found their way into museums.

The Japanese bear (*Ursus japonicus*); the Himalayan bear (*U. thibetanus*); and the sloth bear (*Melursus ursinus*) are among the foreign bears exhibited.

GRIZZLY BEAR.

POLAR BEARS.

HARBOR SEAL, OR HAIR SEAL.

STELLER'S AND CALIFORNIA SEA LIONS.

SEALS AND SEA LIONS.

The common harbor seal of the Atlantic coast (*Phoca vitulina*) is the typical species of a large group of "hair seals" inhabiting the oceans of the Northern Hemisphere. It has a wide distribution and is found on both shores of the Atlantic, ranging well down the coast of the United States. Near relatives are found in the northern Pacific Ocean, in the Caspian Sea, and in Lake Baikal, Siberia. The harbor seal is an interesting creature, spotted in coat, with a little round head, and an inquisitive face. The specimens shown are from the coast of Maine and seem perfectly happy and well in the fresh-water tanks provided for them.

The sea lion pool, just west of the bear dens, is a popular show place with the public. In it are kept the California sea lion (*Zalophus californianus*) and the Steller's sea lion (*Eumetopias jubata*). The California species, so familiar to visitors to the Pacific coast, is the animal usually seen in shows of trained sea lions. It is a noisy animal, and the bark of the male can be heard for a considerable distance. Steller's sea lion is rarely seen in captivity. The park is fortunate in the possession of a fine female specimen which has lived here since 1900. This animal, according to its former owner, came from the Pribilof Islands, but the species is common at points on the Pacific coast so far south as the seal rocks below Monterey. A full grown male of the Steller's sea lion is an enormous beast, very much larger than the female.

Feeding time at the sea lion pool is an exciting occasion. The animals are fed fish, some of considerable size, which are handed or thrown to them by the keeper from the high rocky den at the end of the pool. It is at this time that visitors can best see for themselves what expert and exceedingly rapid swimmers these animals are. A fish thrown anywhere within reasonable distance of one of the sea lions rarely strikes the water, so expert are the animals in catching them.

THE MARSUPIALS, OR POUCHED MAMMALS.

These interesting creatures, although in former periods of time having a wide distribution over the earth, are now confined to Australia and America. They are separated from all the other living mammals by many structural characters. The most interesting point from a popular view is the fact that the young are born at a much earlier stage of development than in other mammals, and are placed immediately by the mother in the marsupium, or abdominal pouch, where they attach themselves to the teats and remain for a long period of growth. The newly born young of the larger kangaroos are no larger than a mouse but by the time they first look out

of the opening of the pouch, some weeks later, they are grown to a point comparable to the ordinary mammals at birth.

The marsupials in America are all opossums or rat-like forms but in Australia and Tasmania there are marsupials to represent many of the variations found in the mammals of the world—wolf, bear, squirrel, flying squirrel, cat, marmot, rat, rabbit, lemur, anteater, and mole are all imitated in superficial points of structure and mode of life.

Marsupials most often seen in collections of living animals are the various species of kangaroos, wallaby, and wallaroo; the phalangers, Tasmanian devil, wombat, and opossums.

KANGAROOS AND WALLABIES.

The larger species, the great gray kangaroo (*Macropus giganteus*), the red kangaroo (*M. rufus*), and the wallaroo (*M. robustus*) naturally attract the most attention. They are showy, breed well in capitivity, and the young animals, in and out of the pouch, are a never-ceasing wonder to visitors. From the time when the young are first noted moving in the pouch it is about three months, with these large kangaroos, before the little animal first puts his head out the opening. Then follows a very interesting and amusing few weeks during which the young is in or out of the marsupium at his pleasure; sometimes with foot or head out in the most grotesque positions. Finally the mother, concluding that it is time completely to wean her offspring, refuses him further admission to the pouch. These kangaroos sometimes attain a size of over 5 feet for the head and body alone; the added length of the great tail makes the animal appear much larger.

Several smaller species of kangaroos are usually kept in the antelope house. Among the most interesting at the present time are the Parma wallaby (*Macropus parma*), the rufous-bellied wallaby (*M. billardierii*), and the brush-tailed rock kangaroo (*Petrogale penicillata*). The rock kangaroos are at home in rough country rather than in level areas; the tail is less robust than in the other species and is not used as a ground rest when the animal stands erect.

The nail-tailed wallaby (*Onychogale frenata*) is a small species in which the tip of the tail is armed with a nail-like thorn after the manner of the lion.

OTHER MARSUPIALS.

The phalanger (*Trichosurus vulpecula*) is another Australian species, largely nocturnal, and with the habit of playing "'possum" like its American relative. It is not active in the cages and is

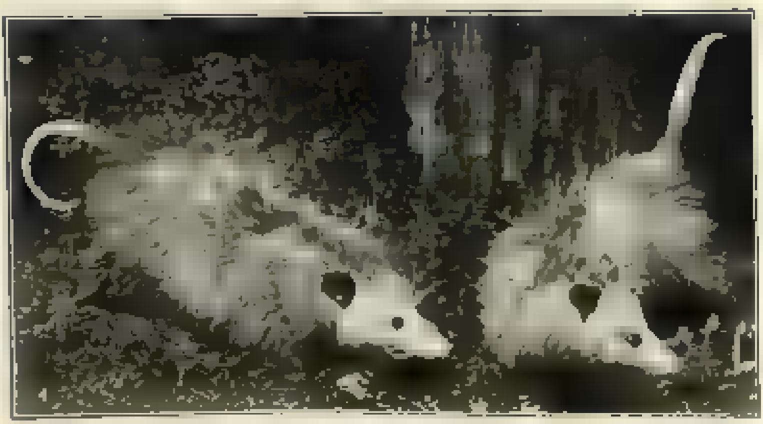
GREAT GRAY KANGAROOS.

RED KANGAROOS.

WOMBAT.

TASMANIAN DEVIL.

GRAY KANGAROO.



VIRGINIA OPOSSUMS.

rather uninteresting in the zoo. The darker Tasmanian form (*T. fuliginosus*), a much more handsome species is represented by several specimens. The wombat (*Phascolomys mitchelli*) is a powerful heavy-set brute, with large head and only a short stump of a tail. It is a burrowing animal and is said to live in small colonies. This is an Australian species, but a closely related form inhabits Tasmania.

All the marsupials so far mentioned belong to a great division of the order known as the Diprotodontia, in which the front teeth or incisors are reduced in number and so placed as to serve best in gathering the herbivorous diet used by the animals. We now come to the more essentially carnivorous or insectivorous section called the Polyprotodontia, in which the incisor teeth are more numerous (four or five on each side of the upper jaw) and the canines are developed after the manner of other flesh eating animals.

The Tasmanian devil (*Sarcophilus harrisii*) is as ugly dispositioned a beast as he is displeasing to the eye. Naturally of nocturnal habits he is not often active in the cage. The Virginia opossum (*Didelphis virginiana*) is likewise of such retiring disposition that he is seldom seen. A small relative, called the murine opossum (*Marmosa murina*) is a native of tropical America and occasionally finds its way into the United States as a stowaway in a bunch of bananas. One recently found hiding in bananas in Center Market was sent to the park.

BIRDS.

Birds (class Aves) are often defined as "animals with feathers" and this diagnosis answers every purpose for popular use, since all birds have feathers and no other animals possess them. No class of animals has received so much popular attention and few so much scientific study as have the birds. Almost any single locality offers a large list of species and the variety to be found during the spring and fall migration makes a study of the birds of any vicinity an interesting and exciting occupation. On account of their great beauty, interesting characteristics, peculiar coloration, or grotesque appearance, most birds are popular as cage pets and the collections in the Zoological Park are great attractions to the public. The great flight cage near the west entrance, the bird house, the waterfowl lakes, the eagle cage, and numerous smaller inclosures are used to exhibit the birds to best advantage. Each variety is given so far as possible the best conditions afforded by the natural features of the park or the resources available for improvements. No complete systematic arrangement of the birds is therefore practicable, but so far as is convenient related birds are grouped together. Twelve or more distinct orders of birds, according to recent schemes of classi-

fication, are commonly represented in the park by numerous species, and some of the most conspicuous or interesting varieties of each group will be mentioned here in proper sequence.

OSTRICH-LIKE BIRDS.

The existing members of this group (Ratitæ) are, with the exception of the kiwis of New Zealand, all large birds. They are incapable of flight but are swift of foot and exceedingly wary, and are, moreover, able to defend themselves vigorously with beak and foot. They are keen of sight and, except the cassowary, are inhabitants of open country.

The ostriches are of maximum size for existing birds, a full-grown male sometimes measuring more than 8 feet in height. They are distinguished from all other birds by having only two toes on each foot. The true ostriches are now confined to Africa and the adjacent portions of southwestern Asia, where several species occur. Two of these forms are shown in the park. The specimen of the great Somaliland ostrich (*Struthio molybdophanes*) was presented to President Roosevelt by Emperor Menelik of Abyssinia, and is a magnificent example of this fine bird. The South African ostrich (*S. australis*) is the species most commonly kept on the ostrich farms in the Southwest, where the bird is reared for its feathers. The adult male ostrich is a splendid bird in his black and white plumage, but the females and young males are of a dull grayish-brown coloration.

The ostrich is represented in South America by the rhea, one species of which (*Rhea americana*) is kept in the park. This is a bird of considerably less size than the ostrich; it has three toes, and its feathers are of less commercial importance. Like its African relative it is an inhabitant of the open country and is found on the pampas of Argentina and on the great plains of southern Brazil and Bolivia.

Australia and the neighboring islands are the homes of a number of ostrich-like birds. The park possesses examples of two of these peculiar types. The common cassowary (*Casuarius galeatus*) is a native of Ceram, but closely related forms occur in New Guinea, Australia, and on other islands. The emu (*Dromiceius novahollandiæ*) comes from Australia. The birds kept in the park have laid many of the beautiful and characteristic dark green eggs, about 10 of which constitute the usual clutch.

THE DIVING BIRDS.

The loons and grebes (order Colymbiformes) are perhaps the most expert of diving birds and their whole structure is developed

SOMALILAND OSTRICH.

CASSOWARY.

EUROPEAN FLAMINGOES.

for life in the water rather than on the land. Most of the species are rapid and strong in flight, once they are in the air, but most of them have difficulty in rising and some are unable to take flight except after a running start over the surface of the water. The legs are placed far to the rear, and on shore the birds must either rest the body on the ground or stand nearly erect. The loons are difficult birds to keep in captivity, but examples have been shown in the park for considerable periods. Most of the specimens received have been virtually untamable, although one bird soon learned to eat fish from his keeper's hand. In the North American waterfowl lake examples of the smaller grebes, or "hell divers" will be found. The horned grebe (*Colymbus auritus*), although a particularly handsome species in spring and summer, is in winter plumage a very ordinary looking bird. It breeds from Alaska and northern Canada to our Northern States, and in winter migrates as far south as Florida.

THE STORKS AND THEIR RELATIVES.

This group (Ciconiiformes) of water birds includes, among other families, the pelicans, cormorants, snakebirds, herons, storks, ibises, and flamingoes. Most of the species are essentially aquatic and some are among the most expert of swimmers. Other kinds are primarily waders, with long legs and with the feet imperfectly webbed. There is likewise great variation in the power of flight and among the diverse species are found some of the swiftest and most graceful as well as the most sluggish of water birds awing.

PELICANS AND CORMORANTS.

The members of the section of ciconiid birds which includes the pelicans, cormorants, and darters are distinguished from the storks and herons by their very short legs and the completely webbed feet; even the hind toe, which is in reality turned sharply inward, is connected by a web.

The American white pelicans (*Pelecanus erythrorhynchos*) are graceful birds on the wing or in the water and very clumsy ashore. In the breeding season a curious horny knob appears on the bill of the adult bird. These pelicans are common in the interior of western North America; the specimens inhabiting the "pelican pond" came from Wyoming. The brown pelican of the Southern States (*P. occidentalis*) and several exotic species are exhibited in summer in the big flight cage.

Pelicans are fascinating birds to watch and frequently reward the observer with some queer antics. On one occasion the flock of American white pelicans in the park was seen to form a circle in the water, all the birds intent toward the center, with bills frequently

submerged. Suddenly the cause of the commotion was apparent, for one of them seized a water snake about 2½ feet long and tossed it some distance in the air. This act was quickly repeated a number of times by different birds until one of the pelicans swallowed the unfortunate snake. He attempted to keep his prey down by holding his bill close to the body, but his efforts were unavailing, for the snake wriggled up into the gular pouch and eventually forced his way out of the pelican's mouth and escaped. One of the pelicans once swallowed a black-bellied tree duck and retained the bird in his stomach for 60 hours, but finally disgorged it, only partially digested. Various unusual objects have been swallowed at different times by the pelicans; a sharp bamboo cutting about 6 inches long worked its way out of one bird's stomach and was removed after it had pierced the lower body. This pelican did not seem to suffer in the least from his experience and did not miss a meal. Three American white pelicans received at the park October 7, 1897, are still living in good health.

Numbers of cormorants (*Phalacrocorax auritus floridanus*) regularly breed in the flight cage, constructing their nests of sticks in the branches of the larger trees within the inclosure. That these birds are well satisfied with their home is proved by the fact that one which escaped and remained away for more than a day returned to the cage; the keeper found him near the door waiting to be let in. During the winter months numbers of cormorants are kept in an aquarium cage in the bird house where the large plate glass front makes it possible for visitors to watch the birds diving and swimming under water for the fish thrown in at feeding time.

A near relative of the cormorant is the snakebird, darter, or water turkey, one species of which (*Anhinga anhinga*) is common in the Southern States and tropical America. This bird also breeds freely in the flight cage. It is an expert diver and has the habit of swimming with the body submerged, only the head and neck appearing above the water—hence the common name of snakebird.

HERONS AND STORKS.

Several species of stork-like birds are regularly kept in the big flight cage; some hardy kinds like the black-crowned night herons (*Nycticorax nycticorax nævius*) and the great blue herons (*Ardea herodias*) remain out throughout the year. The night herons breed within the inclosure, and wild birds of the same species build their nests on top of the great cage and in the neighboring tree tops. More delicate species, including the snowy egret (*Egretta candidissima*), nearly exterminated in the Southern States for the millinary trade, the curious boatbill (*Cochlearius cochlearius*), the white-

SNOW GOOSE AND CANADA GEESE.

THE NORTH AMERICAN WILDFOWL LAKE.

necked heron (*Ardea cocoi*), and the beautiful scarlet ibis (*Guara rubra*), all from South America, have permanent quarters in the bird house. The roseate spoonbills (*Ajaia ajaja*) and several species of ibis summer in the open flight cage, but are kept in the bird house in winter.

The storks, the typical members of this group of birds, are represented by several species, including an American form, the wood ibis (*Mycteria americana*) which is regularly found in the Southern States and in tropical America. The marabou stork, or adjutant (*Leptoptilos dubius*) is a striking bird with a naked head and neck, a powerful beak, and a white ruff above his shoulders; he is native to the Indian region. The common stork of Europe (*Ciconia ciconia*) and the black stork (*C. nigra*) are both shown. The latter is an especially attractive species; shiny black in color, with a white breast and belly, and bright red bill and feet. The white storks nested in the great flight cage during the summers of 1917 and 1918.

THE FLAMINGOES.

These pinkish birds with long legs and neck and angular beak are in many ways connecting links between the stork-like birds and the ducks and geese. Several species are found in parts of tropical America and one formerly occurred in Florida, but the species living in the pelican pond is one of the Old World forms, the European flamingo (*Phœnicopterus roseus*). The birds thrive in this place, but during the colder months when confined in the bird house they are difficult to keep in good condition.

DUCKS, GEESE, AND SWANS.

The most picturesque and ornamental of all the birds for outdoor exhibition in zoological gardens are the true waterfowl, the game birds known as ducks, geese, and swans. Numerous showy species have been domesticated or brought to a condition of semidomestication and other more unusual species are successfully kept in captivity under proper conditions. The group is cosmopolitan in distribution and no less than 67 species and subspecies are known from North America north of the Mexican border. The order (Anseriformes) includes besides the typical family of waterfowl a small group of South American birds known as the screamers.

THE NORTH AMERICAN WATERFOWL LAKE.

In the southeastern side of the park advantage has been taken of the natural topography to reproduce in a measure one of the waterfowl breeding lakes formerly so numerous in the Northern States. For educational purposes, the birds kept in this lake have been re-

BLACK STORK AND AMERICAN WHITE PELICANS.

EUROPEAN PELICANS.

WHITE STORK AND NEST.

stricted to those species known to occur in North America, as enumerated in the check list of North American birds. Bordering the lake on three sides is a tract of land sufficient in size to furnish retired nesting places for the birds and suitable for their varied requirements—woods, thickets, open brushy areas, cane, and cat-tail marshes. The whole tract is inclosed by a vermin-proof fence so that the birds may nest and rear their young in safety. It is the intention to show in this lake as many of the 67 species of North American ducks, geese, and swans as possible, and a good beginning has been made in collecting the birds.

At the present time no less than 144 waterfowl are on exhibition here, including the following species:

Mallard (*Anas platyrhynchos*).
Red-legged black duck (*A. rubripes*).
Black duck (*A. r. tristis*).
Gadwall (*Chaulelasmus streperus*).
Widgeon (*Mareca penelope*).
Baldpate (*M. americana*).
Green-winged teal (*Nettion carolinense*).
Blue-winged teal (*Querquedula discors*).
Cinnamon teal (*Q. cyanoptera*).
Ruddy sheldrake (*Casarca ferruginea*).
Pintail (*Dafila acuta*).
Wood duck (*Aix sponsa*).
Canvasback (*Marila valisineria*).
Redhead (*M. americana*).
Lesser scaup duck (*M. affinis*).
Ring-necked duck (*M. collaris*).
Snow goose (*Chen hyperboreus*).
Greater snow goose (*C. h. nivalis*).
Blue goose (*C. caerulescens*).
Ross's goose (*C. rossii*).
White-fronted goose (*Anser albifrons*).
American white-fronted goose (*A. a. gambeli*).
Canada goose (*Branta canadensis*).
Hutchins's goose (*B. c. hutchinsii*).
Cackling goose (*B. c. minima*).
Brant (*Branta bernicla glaucogastra*).
Barnacle goose (*B. leucopsis*).
Black-bellied tree duck (*Dendrocygna autumnalis*).
Whistling swan (*Olor columbianus*).
Trumpeter swan (*O. buccinator*).

EXOTIC WATERFOWL.

Numerous interesting and beautiful exotic waterfowl are on exhibition in the pelican pond, in the flight cage, and in special inclosures in suitable places throughout the park. Specimens of the graceful mute swan (*Cygnus gibbus*) enjoy the freedom of Rock Creek and nest along its banks. The strange black swan of Australia (*Cheno-

TRUMPETER SWANS.

LESSER SNOW GEESE.

WHISTLING SWANS.

size. Another eagle found in the United States, but with an extensive Old World distribution as well, is the golden eagle (*Aquila chrysaëtos*). It is a fine species, distinguished from the bald eagle in any plumage by the feathered legs.

A number of exotic eagles and vultures, some of which are of great size, share this cage with the American eagles. The lammergeier (*Gypaëtus barbatus*), or bearded vulture, is a large species connecting in many features the eagles with the vultures. It is a native of the higher mountains of Europe, north Africa, and Asia, and many tales of its boldness and strength have been told. The griffon vulture (*Gyps fulvus*) and the cinereous vulture (*Aegypius monachus*) are two conspicuous Old World species kept in this cage. During the early spring months the griffon vultures become very savage and sometimes attack their cage mates—even the eagles are made to suffer on these occasions unless the griffons are removed from the cage. Two specimens of the handsome wedge-tailed eagle (*Uroaëtus audax*) of Australia are kept in this cage. Because it eats the poisoned meat-baits thrown out by the ranchers to destroy the wild dogs, this characteristic Australian bird is said to be rapidly diminishing in numbers, and is in danger of extermination.

INTERESTING RAPTORES IN THE BIRD HOUSE.

Several interesting specimens of eagles and vultures are to be seen in the bird house. The secretary bird (*Sagittarius serpentarius*) is a peculiar African type with long legs, tail, and wings, and a crest of elongated feathers at the back of the head. In appearance it is very crane-like; and is expert in the killing of snakes, lizards, and small mammals.

The harpy eagle (*Thrasaëtos harpyia*) is a tropical American species famous for its strength and spectacular appearance. It is a large species with a long, barred tail, a fine crest, an enormous beak, and powerful feet. It is said to kill fawns, monkeys, and peccaries. The park is proud of its record in having kept a fine specimen of this bird for 18 years. The crowned hawk-eagle (*Spizaëtus coronatus*) is a handsome west African species.

The caracara (*Polyborus cheriway*) or "carrion hawk" is common in parts of tropical America and ranges northward to Florida. Other related species are known from South America.

Various North American and exotic hawks are also on exhibition. The red-tailed hawk (*Buteo borealis*) is one of the common species of the United States which, with other kinds, is much persecuted as a "chicken hawk." As a matter of fact this bird rarely kills chickens and is an industrious destroyer of noxious rodents. One of the smaller species shown is the sparrow hawk (*Falco sparverius*) a

BLACK SWANS.

BLACK-NECKED AND HORNED SCREAMERS.

BARREN GROUND GEESE.

GRIFFON VULTURE.

GOLDEN EAGLE.

CINEREOUS VULTURE.

pretty and valuable species which eats many grasshoppers, mice, and other pests of the farmer. Cooper's hawk (*Accipiter cooperi*), another of the smaller species of America, is more destructive to poultry and birds.

AMERICAN VULTURES.

A group of raptorial birds peculiar to America includes our common turkey vulture or "buzzard," the carrion crow, and the condors. There is little necessity for showing specimens of the turkey vulture (*Cathartes aura*) in cages, since many wild birds of this species make the park their permanent home. The retired wooded slopes bordering the Zoo offer ideal congregating and roosting places for all the "buzzards" of the surrounding country. The birds are encouraged to remain here as an added attraction to the park, and many visitors from Northern States to whom the "buzzard" is an unfamiliar sight are delighted to see them at such close quarters and to watch their graceful flight.

An unusual visitor to the park in 1917 was a specimen of the more southern black vulture (*Coragyps urubu*), a bird rarely seen in a wild state in this vicinity. He appeared one morning with the wild turkey vultures about the buildings and, strangely enough, soon located the cage containing birds of his own species, in the immediate vicinity of which he remained for several weeks.

The California condor (*Gymnogyps californianus*) formerly ranged northward along the Pacific coast to the Columbia River and was an abundant bird in southern California. It is now rarely seen, great numbers having been poisoned by the ranchers in efforts to exterminate the carnivorous animals. A few linger in parts of southern California and in the San Pedro Martir Mountains of Lower California, Mexico. It is deplorable that so fine a member of our avifauna should disappear, but the same fate is in store for other less notable species—even the exceedingly beneficial turkey vulture, after long years of protection, is now under the ban of mistaken legislation and is becoming greatly reduced in numbers in many of our Southern States. Three splendid specimens of the California condor are shown in an outside cage west of lion-house hill.

The South American condor (*Vultur gryphus*) is found up to an elevation of 16,000 feet in the Andes. A splendid specimen of this truly magnificent bird is on exhibition.

Another striking bird of this group is the king vulture (*Sarcoramphus papa*), also of South America. It is a beautifully colored species which has a habit of strutting or dancing with the body held rigidly erect, the wings partially spread, and the head thrown forward against the breast.

GALLINACEOUS BIRDS.

This order includes all of the true "fowls," domestic poultry, and the various species of pheasants, quail, and grouse. It is a group of birds of special interest to the sportsman, since almost all of the so-called upland game birds are members of the order. Many species of gallinaceous birds are of great beauty and are kept purely for show purposes, while others are easily reared in sufficient numbers to stock depleted covers and provide recreation for lovers of outdoor sports. Game keepers have paid much attention in late years to breeding the more hardy and easily kept species and are now turning their attention to experimental work in the hatching and rearing of the more difficult native varieties. An area of considerable size in a retired part of the National Zoological Park has been set aside for experiments of this kind, and particular attention will be given to the North American quail and grouse.

Peafowl (*Pavo cristatus*), wild turkeys (*Meleagris gallopavo silvestris*), and bobwhite quail (*Colinus virginianus*) roam at large and nest within the borders of the park, but until a suitable pheasantry can be established the exhibition of gallinaceous birds must necessarily be restricted to such species as are easily kept under ordinary conditions. A few showy pheasants, two species of African francolins, and several American forms of quail or partridge are kept in the bird house.

The curassows are fine, large gallinaceous birds found from Mexico to South America. There are a number of species, two of which are shown—the Mexican curassow (*Crax globicera*) and Daubenton's curassow (*C. daubentoni*). Unlike most of the forms of this group of birds, the curassows are largely arboreal in habit and nest in trees. The feathers of the back and rump are always soft and downy, unlike those of the other gallinaceous game birds.

CRANES AND THEIR ALLIES.

This group (Gruiformes) includes the cranes, rails, cariamas, and bustards, as well as some lesser known forms. It has a wide distribution, and as its members are frequently classed as "game birds" it has a great popular interest. The cranes comprise some of the most showy of zoological park avian exhibits and are now much sought by private collectors of living birds. The remaining families within the order are less often seen in zoological gardens, but are, nevertheless, all birds of more than ordinary interest to the ornithologist.

One of the finest species, the great whooping crane (*Grus americana*) is bordering upon extinction. It bred formerly from northern Mackenzie south to Illinois and Iowa and occurred commonly in migrations through the Central and Southern States. It is a splendid

CALIFORNIA CONDOR.

SOUTH AMERICAN CONDOR.

AUSTRALIAN CRANE.

JAPANESE CRANE.

CROWNED CRANES.

bird; white, with black primaries and primary coverts. Naturally a wild and wary creature, it rapidly became scarce after its breeding grounds were settled by man, and it is now virtually impossible to obtain specimens. The park is fortunate in the possession of a fine example. In summer this bird may be seen in the great flight cage, but in winter he occupies quarters in the bird house.

The sand-hill crane (*Grus mexicana*) is another American species, still common in parts of Florida and in the Western States. Like the white crane it is a shy bird and difficult to secure, and the rapid settlement of its range has naturally greatly reduced its numbers. In parts of the upper Mississippi Valley, where it formerly bred but now occurs only in migration, it is a bird of the prairies and cornfields where its habits are much the same as those of the Canada goose. Small flocks flying low over the prairies, to and from the feeding grounds, are easily mistaken for geese, but when the birds are migrating, in great circles high in the air, there is no cause for misidentification. At reasonable range, flying cranes are readily distinguished from geese by the long legs, extending backward; and may be instantly known from the blue heron (often erroneously called blue crane) by the long neck, which is held extended forward, and never folded back as with the herons.

A number of exotic cranes, some of striking appearance, are regularly kept in the park. Of the genus *Grus* a number of Asiatic species are shown, including the white-necked crane (*G. leucauchen*) so often pictured in Japanese drawings; the Indian white crane (*G. leucogeranus*); and Lilford's crane (*G. lilfordi*), which represents the common European crane in eastern Siberia. A fine Australian species (*G. rubicunda*) is often called the "native companion."

The Demoiselle crane (*Anthropoides virgo*) of southern Europe and Asia and northern Africa is a pretty little species with white ear tufts; and the crowned crane of Africa (*Balearica pavonina*) is a still more handsome form supporting an erect occipital tuft which is decidedly showy.

THE CARIAMA.

A group of South American birds, now known to be somewhat distantly related to the cranes, includes the cariama and the chunga. The cariama (*Cariama cristata*) might well be called the American secretary bird, for he not a little resembles that famous bird of prey of Africa in general appearance, and has some of its habits as well. The cariama inhabits the high, open country of Brazil, Paraguay, and northern Argentina. Its food is mainly animal, but it also eats berries. It is protected by law in some districts as a destroyer of snakes, and being easily tamed, is sometimes kept about poultry yards.

Specimens of the American coot (*Fulica americana*), representing the rail family, may be seen in the North American waterfowl lake. This bird, often called the "mud hen," or "crow duck" has a wide distribution in North America. It breeds from central Canadian Provinces south to Texas, Tennessee, and New Jersey; and winters from the Central States to northern South America. In many places the coot is classed as a game bird, and properly cooked it provides a very palatable food.

An interesting flightless rail from New Zealand, known as the weka, differs greatly from our common members of the family in habits, as it is a bird of the forest and scrub rather than of wet marshes or lakes. Although the wekas have imperfectly developed wings, and are incapable of flight, they are expert climbers and the inclosure in which they are kept must be covered completely. They are of the size of a well-grown pullet and are quarrelsome and mischievous, even among others of their own kind. Three species (*Ocydromus australis*, *O. brachypterus*, and *O. earli*), all from South Island, are on exhibition. They were received as a gift from the New Zealand Government.

SHORE BIRDS, GULLS, AND PIGEONS.

In most modern systems for the classification of birds, the snipes and plovers, gulls and terns, auks, and pigeons are grouped together in a single order (Charadriiformes), which takes its name from the typical family, the plovers (Charadriidæ.) A few species of "shore birds," as the plovers and snipes are usually called, and some gulls, are regularly kept on exhibition; but the chief interest in the order, so far as zoological gardens are concerned is concentrated on the suborder Columbæ, the pigeons and doves.

The shore birds are difficult to keep without the specially prepared quarters which it is hoped the park can sometime arrange; but from the fact that a specimen of the ruff (*Philomachus pugnax*) was on exhibition in the bird house for over 10 years, the outlook seems encouraging for success with other species of this interesting family. Avocets, stilts, plovers, curlews, and many of the larger snipes, should be as easily kept as the ruff.

Certain members of the gull family are to be seen in the big flight cage. These include the large herring gull (*Larus argentatus*), a species common to the northern parts of both Europe and America which has nested here; and the more tropical laughing gull (*L. atricilla*), a smaller, more graceful species sometimes called the "black-headed gull." A single specimen of the Great black-backed gull (*L. marinus*) has lived in the park since 1905. "Billy," as he is known to everyone, was still in immature plumage when he ar-

GREAT BLACK-BACKED GULL.

OUTDOOR CAGE FOR MACAWS AND COCKATOOS.

LEADBEATER'S COCKATOO. YELLOW-HEAD PARROT.

GREAT RED-CRESTED COCKATOO.

BLUE-AND-YELLOW MACAW.

rived from Labrador. He is everybody's pet, but on account of his quarrelsome disposition he can not be placed in inclosures with any but the larger birds. During the summer season Billy lives in the pelican pond, and although he lords it over the white pelicans, storks, and swans, he is unable to do them serious damage.

PIGEONS.

Numerous species of doves and pigeons are kept in the larger cages of the bird house. These include representatives of the group from many parts of the world, and form a very attractive exhibit. The soft colors and beautiful forms of the various species, as well as their pleasing notes, make them great favorites with all. Among the larger and more showy forms are the snow pigeon (*Columba leuconota*) of the mountains of central Asia, which has the neck, lower back, and breast white; the band-tailed pigeon (*Chloroenas fasciata*) of western North America, frequently confused with the probably extinct passenger pigeon but which may be recognized from that bird by its short, even tail; and the great, plump wonga-wongas (*Leucosarcia picata*) of Australia, curiously marked with white forehead and pectoral bands.

Opposed to these larger species are some groups of small doves, found in both the Old World and in the warmer parts of America which are particularly noticeable on account of their diminutive size. These include the Australian and East Indian members of the genus *Geopelia* known as the peaceful and zebra doves, and the little ground doves (*Chaemepelia*) and Inca doves (*Scardafella*) of the southern United States and tropical America.

An interesting American dove, called the blue-headed quail dove (*Starnoenas cyanocephala*), is a handsome species confined to the Florida Keys and Cuba, where it is said to be rapidly decreasing in numbers. It has a large black throat patch, extending down to the upper breast and bordered by whitish, a white stripe under the eye, and a rich blue crown. Its habits are said to be decidedly quail-like and it is known to the Cubans by the name of "Perdiz."

The Australian crested pigeon (*Ocyphaps lophotes*) has a long black crest which it frequently erects, at the same time elevating the tail until the two almost meet.

CUCKOOS AND PARROTS.

The cuckoos and plantain eaters and the great tribe of parrots, macaws, and cockatoos form the order Cuculiformes. The first group is poorly represented in the average zoological park collection but the parrots and their kindred usually form not a small proportion of any exhibition, and certain species are almost as familiar to the average person as is the common canary.

The plantain eaters are confined to Africa. One species, the crested touraco (*Turacus corythaix*) may be seen in the bird house. In this species the outer toe is completely reversible; at one moment the bird may be perched with three toes forward, the next moment one is startled to note but two, the outer toe having been quickly turned behind. The plumage of the anterior half of the body is of a beautiful green, the bill, eye ring, and some of the wing feathers red, and the erect crest is tipped with white.

PARROTS.

Parrots, including macaws, cockatoos, lories, paroquets, etc., form one of the most strongly marked groups of birds, as easily recognized by their peculiar external aspect as defined by anatomical structure. * * * The tongue is thick and fleshy, in some genera peculiarly brushy; it has a horny nail on the under side at the end, like a human finger, and with this and its papillæ or fringe on the other side forms a delicate tactile organ. * * * Ability to articulate human speech is one of the most notorious faculties of certain parrots. * * * Finally, it may be noted in this connection that the bill is used in *climbing*, like a hand, the upper mandible being much more freely movable upon the skull than is usual among birds. This mobility is secured by the articulation instead of suture of the maxillæ, premaxillæ, and nasals with the frontal, palatals, and jugals. The mandibular symphysis is strong, short, and obtuse; the lower jaw is like a thumb as opposed to the fingerlike upper jaw, and the jaws as a prehensile organ may be likened to the claw of a lobster. (Coues.)

Over 500 species of parrots and their allies are recognized and these are distributed throughout the tropical countries of both the Old World and America. Parrots are not confined to the Tropics, however, since Australia and New Zealand support many species, and in North America the Carolina parakeet formerly ranged northward to Wisconsin. Australia, New Guinea, and South America are especially rich in members of the parrot tribe.

There is always a good representation of these birds in the National Zoological Park. With the exception of the species kept in the outdoor macaw cage near the west gate, all are exhibited in the bird house. In the outdoor cage may be seen several hardy species—the bare-eyed cockatoo (*Cacatoes gymnopis*), the beautiful roseate cockatoo (*C. roseicapilla*), the red-and-blue macaw (*Ara chloroptera*), and the red-and-yellow-and-blue macaw (*A. macao*). The cockatoos are native to the Australian region and the Philippine Islands. They are handsome birds, but their shrill shrieks are unpleasant to hear. Several other species are shown in the bird house, including the sulphur-crested (*C. galerita*), a white species with yellowish head tufts native to Australia and Tasmania; the white (*C. alba*); the great red-crested (*C. moluccensis*); and the beautiful rosy-tinted Leadbeater's cockatoo (*C. leadbeateri*).

The macaws are tropical American birds, mostly of large size and gaudy plumage. In addition to those in the outside cage, other

species, including the yellow-and-blue (*Ara ararauna*) and the Brazilian green macaw (*A. severa*) may be seen in the bird house.

The thick-billed parrot (*Rhynchopsitta pachyrhyncha*) is the only member of the parrot group, excepting the almost extinct Carolina parakeet, known to occur in the United States. At intervals a number of years apart, flights of these birds arrive in the mountains of southern Arizona, coming out of Mexico. The specimens shown were captured in January, 1918, in the pine-forested Chiracahua Mountains, when the ground in the higher altitudes where the birds feed on the pine seeds was covered with snow and the temperature stood at 10 above zero. The thick-bills are exceedingly noisy birds and, as they visited the Chiracahuas in flocks of 150 to 200 individuals, must have presented a spectacular appearance in this wintry environment.

A group of parrots known as the Amazons occur in tropical America. There are about 50 species known, the greater part of which are green with red markings in some part of the plumage. They are common cage species and include some of the best of "talkers." Unlike the macaws, all have short tails. The collection now contains the following species of this group:

Cuban parrot (*Amazona leucocephala*).
Santo Domingo parrot (*A. ventralis*).
Festive parrot (*A. festiva*).
Plain-colored parrot (*A. farinosa inornata*).
Yellow-fronted parrot (*A. ochrocephala*).
Yellow-winged parrot (*A. barbadensis*).
Yellow-naped parrot (*A. auropalliata*).
Yellow-headed parrot (*A. oratrix*).
Orange-winged parrot (*A. amazonica*).
Yellow-cheeked parrot (*A. autumnalis*).
White-fronted parrot (*A. albifrons*).

An African species which is considered to be fully equal to some of the Amazons as a talker is the gray parrot (*Psittacus erithacus*). It is an ashy gray in color, with black wing feathers and red tail. A very attractive group of parrots, many species of which are popular as cage birds, is the group known as the parakeets. These are all small birds, some of them actually diminutive. One of the commonest forms kept as a pet is the shell parakeet, or Australian grass parakeet (*Melopsittacus undulatus*). This species breeds in captivity, nesting in a small box placed within its inclosure. In a wild state it is said to flock by thousands and spends a considerable portion of the time on the ground, feeding upon the seeds of grasses. The love bird (*Agapornis pullaria*) belongs to an African section of the parakeet tribe and is also popular as a cage pet. The park is fortunate in the possession of a splendid specimen of the black-tailed parakeet (*Polytelis melanura*), a handsome Australian species now very rare.

The Australian region is inhabited by another group of beautiful parrots known as lories, several species of which are usually exhibited.

One of the most remarkable of all the parrot tribe is the kea, or mountain parrot (*Nestor notabilis*), confined to the South Island of New Zealand. This bird was formerly abundant in the mountainous parts of this region but owing to its acquired habit of killing sheep has been so reduced in numbers that specimens are now very difficult to obtain. The flock exhibited in an outdoor aviary near the bird house was received as a gift from the New Zealand Government. It was more than 10 years after the kea was first discovered in 1856 before it was suspected that this bird had developed the habit of killing sheep, and there was considerable doubt expressed for a number of years. It has been definitely proved since that although all the individuals of the species have not acquired this remarkable change of habit, many of the birds do really kill full-grown sheep. The kea lights on the rump of the sheep, clinging to the wool, and drives his sharp beak into the unfortunate animal's back. The fat, flesh, and intestines of the sheep are eaten by the birds, who frequently go in large flocks.

KINGFISHERS, HORNBILLS, AND OWLS.

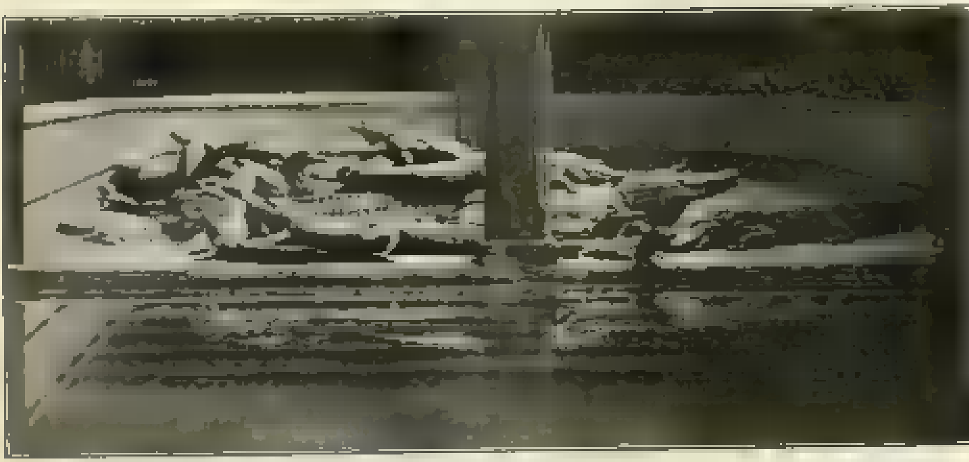
The kingfishers, hornbills, and owls are members of an order of birds (Coraciiformes) which includes other seemingly unrelated families—as the woodpeckers, humming birds, goat-suckers, and swifts. It is what Coues calls a "miscellaneous assortment, grouped together more because they differ from other birds in one way or another, than on account of their resemblance to one another." Recent anatomical studies have, however, shown the actual relationships in many cases.

Passing through the bird house one may be suddenly startled by a loud, rapidly executed, and prolonged cackling laugh. This is from the throat of the giant kingfisher, or laughing jackass (*Dacelo gigas*) an Australian bird related to our common American kingfisher, but of a decidedly greater size. Near by is a representative of the hornbill family, the concave-casqued hornbill (*Dichoceros bicornis*), a native of the Malay region. Hornbills are found in the forests of Africa, India, and many of the eastern islands, and are hunted for food by the natives of some districts. In many regions, however, these grotesque birds are regarded with considerable superstition and are rarely molested. These remarkable birds have a most curious nesting habit. A large cavity in a tree is selected for the nest and the female hornbill is confined therein by a plaster wall, both birds apparently taking part in the process of masonry, which makes her a prisoner until the young are hatched. During the in-

CONCAVE-CASQUED HORNBILL.

SCREECH OWL.

BARRED OWL.



ALLIGATORS.

ALBEMARLE ISLAND TORTOISE.

cubation period she is fed by the male through a small hole left in the wall, but is said to come forth in a much emaciated and dung-bespattered condition.

In an inclosure near the big flight cage are some 15 specimens of the great horned owl (*Bubo virginianus*), one of the largest of the American birds of prey, as well as one of the most destructive to smaller birds. Other owls, including the highly beneficial species known as the screech owl (*Otus asio*) and the barred owl (*Strix varia*), are kept in the bird house.

THE PERCHING BIRDS.

More than half of all the species of birds known in the world belong to the order Passeriformes, frequently called the "perching birds," and typified by the sparrows. There are numerous families and the vast majority of species are small or medium sized birds; the largest North American species are the crow and raven.

In some of the larger cages of the bird house numerous species of this order of birds are shown. There will be seen many of the more familiar native species as well as rare and beautiful exotics. In near-by cages are some of the larger representatives of the order, including ravens, crows, magpies, and starlings from various corners of the earth. Among the most attractive of the smaller birds are the numerous species of the finch or sparrow family of which the common canary (*Serinus canarius*) is a familiar member.

The weaver birds, native to Australia, India, and Africa, attract a great deal of attention; this is especially true of the species known as the paradise weaver (*Steganura paradisea*) which grows tail feathers of great length in the breeding season.

REPTILES.

Reptiles (class Reptilia), as distinguished from mammals and birds, are "cold-blooded." The temperature of the animal is greatly influenced or even regulated by that of the surrounding air, or of the water in which it lives. There is considerable popular confusion as to the distinction between reptiles and amphibians, sometimes called batrachians (class Amphibia), including the frogs, toads, and salamanders.

From Batrachians, Reptiles differ in breathing by lungs during the whole of their existence, and not by gills as do the former during at least part of their life, and by the fact that the skull, which in Batrachians, as in Mammals, articulates with the vertebral column by two rounded knobs or condyles, is in Reptiles attached as in Birds by a single condyle. Unlike Batrachians, they undergo no metamorphosis, being born in the condition which they will retain for the whole of their life. In the majority of Reptiles the skin is covered with scales or shields, while in Batrachians it is, with a few exceptions, naked. (Boulenger.)

Three orders of reptiles are represented in the park collections. These are the turtles and tortoises (Testudinata), alligators and crocodiles (Loricata), and the lizards and snakes (Squamata). One of the urgent requirements of the National Zoological Park is a suitable reptile house, where larger collections of these interesting creatures may be exhibited. At present the reptiles are kept in quarters in the lion house.

TURTLES.

Those turtles living entirely on land are often arbitrarily distinguished from the aquatic species (true turtles) and the semi aquatic forms (terrapins) under the name tortoise. Some of the tortoises are small in size, like our common box turtle of the Eastern States; while others, particularly some of the island species, grow to an immense size and are supposed to live to a greater age than any other animals. These giant tortoises are now known only from a few islands in the Indian and Pacific Oceans, on some of which they were excessively abundant up to comparatively recent years. Visiting ships have now so greatly reduced their numbers that on most of the islands they are completely or almost exterminated. On certain of the Galapagos Islands, some 500 miles off the coast of Ecuador, giant tortoises were found in great numbers within the last century, and on certain of the islands were fairly common less than 20 years ago. In addition to the thousands carried away by vessels as food for the crews, great numbers have been killed for the oil alone.

A number of species of giant tortoises have been described from the Galapagos, and it is believed that most of the islands of the archipelago have developed separate forms; and on at least one island two distinct species were found, separated by a natural barrier. The food of these curious creatures is chiefly grass, although at certain seasons a great quantity of cactus is eaten. Mr. Edmund Heller, who visited the Galapagos Islands in 1898 and 1899, collected one specimen which had the whole palate and pharynx bristling with cactus spines, and noted that the tortoises eagerly devoured the stems and fruit of the cactus quite unmindful of the spines and apparently without suffering. Heller states that the tortoises are quite active, and though slow are so persistent in their journeys that they cover several miles a day.

Specimens of two species of Galapagos tortoises were obtained for the park collection from the material collected by the Rothschild expedition to the islands in 1897. The Albermarle Island tortoise (*Testudo vicina*) is perhaps the largest living tortoise, and specimens have been known which were over 4 feet in length and prob-

ably weighed nearly 400 pounds. The Duncan Island tortoise (*T. ephippium*) is somewhat smaller.

In the pine barrens of the Southern States, a comparatively large tortoise, curious for its burrowing habits, is known as the gopher. This species (*Gopherus polyphemus*) grows to a length of 15 inches and a specimen almost of that size from peninsular Florida is on exhibition. Like the giant tortoises this species is herbivorous and is particularly fond of fruits of various kinds. Related species are found in the arid regions of the Southwest, and in other parts of the world.

The common eastern tortoise or box turtle (*Terrapene carolina*) is found wild within the park. It it a smaller species than the gopher and the plastron or lower shell is so hinged as to permit the animal when alarmed to close itself completely within its armor. A western species (*T. ornata*) is also shown.

Specimens of the common native snapping turtle are sometimes captured within the park. One of these reptiles caused considerable damage among the waterfowl in the beaver pond before he was finally caught by the keepers.

ALLIGATORS.

The common alligator of the Southern States (*Alligator mississippiensis*) is well known to a large proportion of our people; thousands of the young have been carried by tourists from Florida to all parts of the United States. The species formerly was abundant in fresh-water streams and swamps throughout its range—north to North Carolina and west through the humid portions of Texas. In all of the more accessible and settled portions this reptile has suffered greatly from hunters, professional and amateur; and in most parts of its former range it is now a rare thing to see an alligator of any size. In some of the streams and swamps of the wilder places within the Gulf States, however, it is still possible to find alligators from 6 to 8 or 9 feet in length; but the 10 to 16 foot reptiles are practically gone.

The nest of the alligator has frequently been described to me by old residents in Florida as resembling the nests made by the wild "razorback" hogs of that country. It is a great mound of muck, grass, moss, and sticks; placed in a retired spot, and is said sometimes to be carefully guarded by the female. The numerous eggs are hatched by heat generated by the rotting vegetation. On very good authority it is stated that the Florida alligator deposits its eggs in the sand where they are hatched by the heat of the sun. In some portions of the State this is doubtless the case, but the building of the nest of vegetation is the common habit in localities with which

I am familiar. The roar or bellow of the larger alligators may be heard for a considerable distance and while hunting in the canebrake region of northeastern Louisiana in early spring I have lain awake in my blankets far into the night listening to this strange, wierd call. Along the Mississippi River below New Orleans where the muskrats have caused such serious losses through damage to the levees, the alligators, recognized as the principal natural enemy of these burrowers, are protected by local laws.

The alligator pool in the Zoological Park contains about 25 specimens of various sizes; but the smaller individuals, some under a foot in length, have special quarters. The larger alligators are cannibals and when hungry do not hesitate to swallow the young of their own species.

THE LIZARDS.

Most of the American lizards are graceful and innocent creatures and many are beautifully colored. They are as much a delight to students of reptiles as our warblers are to the ornithologists. There are, however, two large species, found in the Southwest and in Mexico, which are dangerous reptiles. They are known as the beaded or tuberculated lizards, are sluggish creatures inhabiting arid situations, and are the only known poisonous lizards.

The Gila monster (*Heloderma suspectum*) is known only from portions of Arizona, New Mexico, Sonora, and southern Nevada. It is a comparatively large species, growing to 20 inches or more in length. In color it is brown or blackish, marked with numerous rings and blotches of yellow or orange. The upper parts are heavily beaded or tuberculated; the tail is fat and stumpy, and the reptile presents altogether a dangerous and terrifying appearance. On account of his notorious disposition and because of his poisonous bite, the Gila monster is much dreaded by residents of the region in which he lives; and the several specimens on exhibition attract great attention. The poison glands are situated on the outer side of the lower jaw near the tip. When biting the Gila monster holds on like a bulldog so that the poison may have time to become absorbed in the wound. No specific antidote is known.

The iguanas, large lizards of tropical America, are represented in the collection by the rock iguana of Mona Island, near Porto Rico. This species (*Cyclura stejnegeri*) sometimes reaches a length of over 3 feet. It is a ground-inhabiting reptile and is chiefly vegetarian in diet. Iguanas are much sought by the natives for food.

Several species of the commoner lizards of small size, native to the Southeastern States, are shown. The glossy blue-tailed skink (*Eumeces quinquelineatus*) is one of the most handsome of the eastern forms. It is common in pine woods, especially in the South. The

GILA MONSTER.

STUMP-TAILED LIZARDS.

rough-scaled species, known as the swift (*Sceloporus undulatus*), and the little lizard, called the "chameleon" (*Anolis carolinensis*), are both abundant in favorable localities in many parts of our Southern States. The latter species has the habit of changing color and may be at times gray, green, or its normal shade of dull brown.

Two interesting species of Australian lizards on exhibition are the blue-tongued lizard (*Tiliqua scincoides*) and the stump-tail (*Trachysaurus rugosus*). The blue-tongue grows to a length of nearly 2 feet and, as its name implies, is provided with a large fleshy tongue of a brilliant blue in color. It is sluggish in habit and is particularly fond of bananas and other fruits and milk. The stump-tailed lizard is another sluggish species, reaching 14 inches in length. The tail is broad and flattened and the reptile has the habit of giving it quick jerks, so that at first sight it is puzzling to distinguish the head from the tail. It is said to kill snakes.

SNAKES.

While it is probably true that the great majority of people dislike snakes it is also true that a collection of these reptiles attracts extraordinary attention and adds greatly to the interest in a zoological park. The larger snakes in particular are a never-ceasing source of wonder to visitors, and the more spectacular of the lesser species, like the rattlesnakes, are almost as popular an exhibit.

The prize specimen in the snake department of the National Zoological Park is a fine example of the anaconda (*Eunectes murinus*), or water boa, of South America. The anaconda is the largest of the American snakes and sometimes attains a length of over 20 feet. In color it is a yellowish green, marked with blackish spots. Anacondas are essentially aquatic and spend much time in the water, although they are perfectly at home in trees and are expert climbers. The numerous young are born alive. The largest specimen in the park collection has been here since August 17, 1899, and was a gift from the governor of the State of Para, Brazil.

In a near-by cage are three specimens of the Indian python (*Python molurus*), native to India, the Malay Peninsula, and Java. The largest snakes known are of a related species (*P. reticulatus*); there are apparently reliable records of individuals over 30 feet in length. Pythons, like the boas, are constrictors, and kill their prey by crushing. The pythons lay eggs, which are hatched by the mother who coils around them. The eggs number from 50 to 100. These snakes are particularly fond of climbing and the specimens in the park collection spend much time coiled in the tops of the small trees within their inclosure. The diamond snake (*Python spilotes*), found only near the east coast of Australia, is blackish with a yellow spot

in the center of each scale. It is one of the most attractive of the pythons in captivity and the specimens in the collection are much more active than is usual with large snakes. A closely related form known as the carpet snake has a much wider distribution in Australia.

The common boa, or boa constrictor (*Constrictor constrictor*) is a tropical American species of large size, but considerably smaller than the Anaconda and the larger pythons. It is said rarely to reach a length of 12 feet. Several examples are shown, the largest of which came from Trinidad and is about 10 feet in length. A small specimen of the boa was found in the Washington Market packed with a bunch of bananas, and was sent to the park. This involuntary stowaway is doing nicely in his new home. Other species of boas are found in South America, the West Indies, and, strangely enough, in Madagascar. The tree boa from Trinidad (*Boa enydris*), in a nearby case, is of a smaller species, yellow in color, and with a head much larger in proportion to the size of the serpent. Although an ill-tempered snake, it is, like the boa constrictor, a nonpoisonous species. It sometimes grows to a length of 6 or 7 feet.

Many species of North American snakes are usually on exhibition. Most of these are of comparatively small size but some of them are of great beauty and others are interesting because of their terrible appearance and deadly poison. In the latter class may be mentioned the rattlesnakes and copperheads.

The rattlesnakes are confined to America where many species are known, the majority of which are found in the western United States. The common or banded rattler (*Crotalus horridus*) was formerly found in many parts of the Eastern States, north into Maine, but has now disappeared from much of its former range. It sometimes grows to 5 feet or more in length. The largest rattler is the diamond-back (*C. adamanteus*) which in its typical form in the Southern States reaches an immense size. Many specimens are on record from Florida which measured over 6 feet in length and there are apparently authentic accounts of diamond-backs of between 8 and 9 feet. The bite of one of these large rattlers is very likely to prove fatal.

Closely related to the rattlesnakes are the moccasin (*Agkistrodon piscivorus*) and the copperhead (*A. mokasen*). Both are poisonous species. The copperhead is one of the most dangerous snakes in the Eastern and Southern States because he holds his own in thickly settled communities: they are not uncommon about Washington, especially along the upper Potomac above the city. Adult specimens are commonly from 24 to 30 inches long. In color, the copperhead is hazel brown, with a series of hourglass-shaped darker blotches along the back. Equally venomous is the moccasin, or

cottonmouth, but he is an aquatic species and does not range so far to the north as does the copperhead.

The common water snake (*Natrix sipedon*) and the southern water snake (*N. taxispilotus*) are often mistaken for the moccasin; they are ill-tempered snakes but harmless, and on close examination may be distinguished from the moccasin and copperhead by the absence of the deep "pit" between the eye and nostril, a characteristic feature of those venomous species and the rattlesnakes. The specimens shown of a related species, known as the water coral snake (*Helicops angulatus*), were captured in Trinidad and were sent to the park with other reptiles from that island by Hon. Henry D. Baker, American consul at Port of Spain.

Other harmless American snakes kept in the collection are the black snake (*Coluber constrictor*) sometimes called the "blue racer," and his near relative, the coachwhip snake (*C. flagellum*), both of which sometimes attain a length of 5 feet. Several species of the pretty little garter snakes, as well as the king snake, the pine snake, chicken snake, bull snake, gopher snake, and others are commonly shown.

THE SEA AS A CONSERVATOR OF WASTES AND A RESERVOIR OF FOOD.

By H. F. Moore,
Deputy Commissioner, U. S. Bureau of Fisheries.

(With 8 plates.)

Of the many vast and complex problems confronting a country at war, that of supplying the armies and civil populations with food is one of the most vital and intricate. That it is fundamental needs no demonstration, and one of the first acts of a belligerent is to take steps to conserve and, if possible, increase its food supply. With the acts to that end, the effort to curtail waste, to regulate distribution, the fixing of minimum prices and other measures to stimulate the production of the farm, we are all now familiar.

Measurable success has been attained in the reduction of waste in the household and elsewhere, although the consumer is not yet fully "doing his bit," and crops of many kinds show great increases over the yields of previous years, though the meat crop, which supplies the major part of the high priced ingredient in our diet, protein, does not, and probably can not under present conditions, respond to these measures. It requires time to produce meat animals, particularly beef, and the food which they require is expensive and its production requires acreage which can be used in many cases for crops directly convertible to human use.

Fortunately with this condition confronting us there exists a food supply dietetically equivalent to meat which requires no "raising" but may be had for the catching. This is found in the fish of the sea and the Great Lakes and, in smaller quantity, in the minor lakes, ponds, and streams. The sea, in particular, is a vast reservoir of food produced without effort on the part of man. It contains numerous fish of many kinds, some of them preying on other fish smaller, weaker and less swift than themselves, others feeding on invertebrates swimming in the water or resident on the bottom, and still others consuming marine vegetation usually microscopic in size, but all dependent directly or indirectly on plant life.

That "all flesh is grass" is as true in the water as it is on the land. Since it was precipitated from the vapors which enveloped

the earth when it was much hotter than it is now, the sea has been accumulating a wealth of materials, the most conspicuous of which is the salt which makes it briny. These have been leached out of the rocks and soils and, in a way, the sea may be said to be a solution of the land. It even contains traces of such inert substances as the precious metals like gold, but its really precious store consists of the same minerals which make our productive soils, or which the farmer supplies to his land when he fertilizes it. In fact, some of the very fertilizer for which the farmer pays, and which through carelessness or misfortune is washed from his fields into the watercourses, undoubtedly finds its way in course of time to add to the sea's store. It is not entirely lost to man, for with other materials of its kind it becomes converted into marine vegetation, just as some of it would have entered into farm crops if it had been left in the fields. It produces not only the "sea weeds" of the grosser kind, with which every visitor to the seashore is more or less familiar, but a wealth of microscopic plants, individually too small for human vision, but of an aggregate volume surpassing comprehension, some of them floating freely in the water and others forming carpets on the bottom in the shallows or patches on every fixed or floating body. This vegetation, in general, is more luxuriant in proximity to the coast than in the waters far removed from land, and this is true not only of the bottom dwelling forms, which can not live in the lightless regions of the great depths, but of the floating species which dwell at or near the surface. The abounding plant life near the shores, and particularly in salt and brackish estuaries and lagoons, is probably in no small degree correlated with the never-ceasing flow of fertilizer materials, the wash of the soil, which the rivers bring down to the coasts.

It is this vegetation, but particularly the microscopic kinds, both bottom dwelling and floating, which forms the great pastures of the deep on which the animal life of the sea is as rigidly dependent as are the land animals on the produce of the soil, and of which man indirectly avails himself when he partakes of sea food.

There are many interesting adaptations of structure and habit which complete the cycle from the soil through the sea and back again to the land, but one instance will suffice as a type. The wash from a carelessly tilled farm, or the waste of a household, finds its way into a river on the Atlantic coast and is carried in a state of solution to one of the estuaries or bays which indent the shore line. There it is absorbed as nourishment by one of a group of microscopic plants known as diatoms, which use the same sort of food and elaborate it in the same way as land plants, but obtain it from the dissolved materials of the water in which they are bathed, instead of seeking it through the medium of roots thrust into the soil and leaves

expanding to the air. These little plants grow and swell with added substance, and each eventually cleaves in two and the progeny themselves divide in turn until vast numbers are produced.

The coastal waters in which this occurs are the feeding grounds of the menhaden, whose food consists solely of minute aquatic organisms which it strains from the water at and near the surface. The throat of the menhaden is lined with a series of fine filaments attached to the gill arches like the barbs of a feather to the side of the quill, and these overlap one another so as to make a beautifully fine screen through which the water taken into the mouth must pass before it can gain exit through the gill openings. Thus equipped, the fish swims open-mouthed, screening out of the water and swallowing the minute organisms, many of which are the little plants previously mentioned, and the others, almost equally small animals which feed on those plants.

Although the menhaden is a relative of the shad and the herring, and has excellent food qualities of its own, it is not generally eaten, possibly because it has long been known as a source of oil and fertilizer. It is extremely abundant, moving in large schools which are preyed on by many of the most prized of our food fishes, and when we eat one of them we bring back to the land something with which the land parted at the beginning of the cycle. If we eat the menhaden itself this return is accompanied with the utmost directness and economy.

The sea, therefore, is a great conservator, receiving and storing, and making available for man's use in another form, much matter which at first sight seems irretrievably lost. It is for man to determine whether he will use this store, particularly at a time when deficiencies are appearing in the supply of what he is accustomed to use.

It is the general verdict of those versed in the science of dietetics and home economics that the consumption of fish in American homes is far below what it should be. The composition of fish is essentially the same as that of meats and poultry. Pound for pound, dressed fish of all kinds are approximately as rich in protein as beef, mutton, and chicken. The quantity of fats varies in the different kinds and with the season, but in general it is less than is contained in meats. The protein, however, is the important constituent, as there is no substitute for it in the diet, while fats can be supplied from other and cheaper sources, and to some extent be replaced by starches and sugars.

In the diet of the average family in the United States, meats and poultry furnish many times as much of the protein as is supplied by fish, notwithstanding that the latter affords it at a lower cost if reasonable judgment be displayed in marketing.

There are various reasons for this, one of them being that there has been engrafted on the national habit the irrational custom of eating fish but one day each week. Another is that fish has not been as carefully handled [redacted] it should be, with the result that at times it has not reached the consumer in the best condition, and the latter has thought that he does not like fish, when in reality his distaste has been for stale fish. There are other reasons which it is not necessary to discuss, as many of them are being overcome by the "eat more fish" campaign which is being so vigorously waged as a war measure. The people are beginning to eat more fish, and the problem now is to give them the fish to eat.

In consideration of what has been said about the abundance of the supply of fish food in the sea, the obvious way of meeting the demand would be to catch more fish, but unfortunately this can not be easily done, under present conditions, by the simple expedient of increased effort. Fishing involves the use of labor and material and, particularly when conducted on the high seas, requires experience and skill, while the diversion of many of the young and active fishermen to military duties, especially in the Navy, has left a gap which it would be difficult to fill at any time, but especially so now when the demands for labor in other fields are insistent and the pay is lucrative. In addition, a number of the best fishing vessels have been called to naval service, and the war demands for linen thread, which is extensively used in making gill nets, are making it difficult to maintain even the existing intensity of some of our most important fisheries.

The case, however, despite difficulties, is far from hopeless, and the consumption of fish can be easily doubled with present facilities. Unnecessary restrictions on some of the sea fisheries may be relaxed, but as fishery legislation is intended for the conservation of the ultimate supply care must be exercised in letting down the bars lest the future be jeopardized for the sake of the present. There are also enormous wastes in the spoilage of fish in transportation to the markets and awaiting sale, and these may be overcome by better care and icing of the fish, the avoidance of long hauls when markets may be found nearer to the points of production, more expeditious handling by the transportation companies, and more prompt consumption, such as can be induced by making every day a fish day, instead of holding the supply to meet the exclusive demand of Friday. Fishermen work every day, and that part of their catch which is a week in reaching the table is often not as fresh as it should be, and in many cases is spoiled beyond usableness.

There is another great waste which can be readily corrected through the cooperation of dealers and consumers, and it is the particular purpose of this article to call attention to it, although the

point has been somewhat slowly arrived at in order that the reader might approach the subject with an understanding of antecedent and collateral conditions, and be in a better position to appreciate its importance, and his responsibilities and opportunities. This is the waste of large quantities of good, in many cases excellent, food fishes caught unintentionally and thrown away in whole or in part for lack of a market.

Fishermen set their nets, or fish their gear of whatever kind used, for one or several kinds of fish having a market value and reputation, but incidentally they catch quantities of other species collectively known as "trash," which are either thrown away to become a nuisance near the fishing grounds, or are used for inferior purposes, such as the manufacture of oil and fertilizer. There are other sea foods readily obtainable in great quantities that are not taken at all merely through ignorance of their availability or qualities, and are wasted in the sense that they are not utilized.

The aggregate of this wasted and neglected food supply is enormous, and it is probable that, if it were all used, the supply of sea foods—including in that term fresh-water products—could be doubled with little additional effort on the part of the fishermen. The Bureau of Fisheries has given considerable attention to this subject and has introduced some of these neglected foods into consumption. The exploitation of others is being taken up as rapidly as possible.

One of the most abundant shellfishes of the North Atlantic and Pacific coasts is the sea mussel (*Mytilus edulis*) and, as it feeds on minute particles of vegetable matter, it, even more than the menhaden, is a highly efficient agent in the recovery of land wastes carried into the sea. Although the gills are quite different from those of the menhaden, they also serve not only the purposes of respiration but as filters, the pores of which are so fine that they can be seen only on powerful magnification. The gills are clothed with innumerable little fleshy processes or cilia which, lashing rhythmically, by their united action draw into the open mouth of the shell currents of water which pass through the minute orifices and gain exit by another channel. The little water-carried plants and particles of vegetable detritus which compose the mussel's food, although individually too small to fall within the range of unaided vision, are too large to pass through the pores, and become trapped in the mucous coating of the gills and pass in a steady stream into the mouth, and thence into a long alimentary canal in which they are digested.

From experiments conducted with oysters, which have somewhat similar gills, it is probable that, to get its daily meal, a mussel 3 or 4 inches in length filters from 25 to 50 gallons of water each 24 hours, between 2,000 and 4,000 times its own bulk.

The sea mussel begins its active life as a very minute organism, covered with little cilia, somewhat like those which clothe the gills of the adult, and through the activity of these it has a feeble mobility of its own, although dependent for its larger locomotion on the currents of the water in which it is suspended. Like other lamellibranch or bivalve Mollusca, it is exceedingly prolific, producing young in myriads to be disseminated broadcast by tidal currents and, after a brief, vagrant existence, to settle down and become attached.

The oyster becomes fixed by its shell, but the mussel anchors itself to the bottom or to bodies in the water by means of a tuft of black fibers, the byssus, or so-called beard. The flexibility of this anchorage and the fact that the shells lie with their long axes vertical, permits a given area of bottom to support a density of population almost incredible. In places, extensive beds have been found, with an average crop of 4,000 to 6,000 bushels per acre, and when it is understood that these were produced within a space of two years and that on account of the thinness of the shells the proportion of meats to total bulk is greater than in oysters, in some measure the potential food value of these beds may be realized.

This delectable shellfish is abundantly used and much prized in Europe, particularly in England and France, where the natural supply is supplemented by a rather elaborate system of mussel culture, but it is very little known, except to a few gourmets, in most parts of the United States. A few years ago the Bureau of Fisheries introduced it in the markets of Boston and other cities in New England, where it has become an established commodity, but some difficulty was encountered in providing a steady supply on acount of the reluctance of the fishermen and oystermen to undertake something new. The general awakening to the necessity of providing new sources of animal food, induced by the emergency conditions of a country in a state of war, has excited interest on the part of potential mussel producers, and new supplies are being developed.

The mussel as a food is palatable, digestable, nutritious, and economical. It can be prepared in a great variety of ways, adaptable to almost any taste. It can be cooked in practically any way in which the oyster may be used, and the French have devised many particularly palatable recipes, as can be testified by almost any person who has lived in France. When our troops come home, many of them will bring back agreeable memories of this mollusk.

One of the causes operating against the use of some of the best of our food fishes is the prejudice against the unusual in form or color. "Fish" to most persons suggests a certain definite type of shape and general appearance, and anything which departs materially from this preconception is regarded with suspicion. The goose-

fish is one of the most ungainly and extraordinary appearing of our fishes. Its body is broad and squat, the head is enormous, and the breadth of its mouth, measured on its arc, is almost equal to half the length of the entire body. The jaws are each armed with a double row of formidable teeth, and the entire margin of the body, including the lower jaw, is fringed with ragged fleshy barbels. A peculiar feature is a long staff with a fleshy flag at its tip, which represents the first spine of the dorsal fin, which has migrated from its normal position on the back to the top of the head, where, it is asserted, it serves as a lure to attract smaller creatures within reach of the mouth. The size of the stomach is commensurate with the maw, and the voracity of the fish is in keeping with both, its meals during the day sometimes weighing half as much as itself.

Its food consists of almost every kind of animal which the mouth can take in, fishes, starfishes, mollusks, lobsters, crabs, and even waterfowl. It is recorded that seven wild ducks have been found in a single fish. Its habit of catching geese is said to have given it the common name here used, while the great size of the organ which enables it to take such large prey has given it another of its numerous names, "all-mouth."

The eggs of this extraordinary appearing fish are as remarkable as the adult, and are found inclosed in great numbers in floating, jellylike rafts sometimes 25 to 30 feet long and 4 or 5 feet wide, greatly exceeding the parent in bulk. The paradox of the comparative dimensions of the parent and the egg masses is explained by the fact that the mucus in which the eggs are embodied when they leave the fish swells enormously by imbibition of sea water.

The description of the goosefish may not sound alluring, but nevertheless it is an excellent fish, and in some European markets brings a higher price than the universally esteemed mackerel. The flesh of the body is firm and rather gelatinous in consistency, white, fine grained and practically boneless, and analysis shows it to contain somewhat more protein than some of the common food fishes and about as much as sirloin steak if allowance be made for the greater quantity of waste in the latter as purchased in the market. This good food is practically all wasted in the United States, whereas about 6,000,000 pounds are consumed annually by Great Britain. It has been estimated that at least 10,000,000 pounds are caught incidentally in American fisheries and thrown away.

The sharks and rays collectively constitute another group of fishes which popular prejudice has relegated to the waste pile, although there is nothing repulsive in their appearance. They are all free of the mucus or slime which makes some fish unattractive in the mass, but is usually washed away before they reach the ultimate consumer,

and the sharks at least have lithe and graceful forms, with lines as finely molded as those of a clipper ship. The prejudice in this case is based on the reputation which these fish have as "man-eaters." As a matter of fact there are no man-eating sharks in the sense that they generally or even frequently feed on human beings. There are rare cases of men being injured or killed, and probably partially devoured by one or several of the larger species of shark, but these are mere infrequent accidents like the killing of children by hogs, and from the standpoint of the character of their diet there is more reason for eating shark meat than there is for eating pork.

The food of sharks is in general like that of other carnivorous fishes. There are some that feed on crabs, shrimps, and other bottom-dwelling animals, such as are eaten by the cod and some of its relatives, and some which confine themselves to a fish diet, like the blue-fish and others. They are all habitually "clean" feeders, but when hungry some of them will attack anything of suitable size.

They are eaten in many parts of the world, frankly as sharks, and considerable quantities of the moderate sized species enter the New York market where most of them are sold fresh as "sturgeon," "ocean or deep-water swordfish," or otherwise under the guise of species more generally known to the public.

Some sharks are solitary in their habits, or nearly so, but others, particularly the smaller species, occur in great schools which range over the sea and appear sporadically in the coastal waters at certain seasons, when their rapacity is such as to cause great harm to the fisheries through the destruction wrought on the common food fishes and the injury inflicted on the fishermen's nets and lines. One of the most common of these piratical little sharks is the spiny dogfish, which has been on the market smoked and canned for about a year. As there are several other sea and fresh-water fishes, and even a large salamander bearing the name "dogfish," and as it is used opprobriously by the fishermen, exasperated at their losses, the Bureau of Fisheries changed its official name to grayfish, and it is known as such in the market.

The food qualities of the sharks vary somewhat with the species, some having a strong and others a bland flavor. Their nutritive value as shown by analysis, and their digestibility as tested by feeding experiments, is about the same as that of other fishes and meats. They differ from other fishes, from meats, and particularly from poultry, by being entirely free of uric acid, and by possessing a much higher content of urea and ammonia. These latter substances are harmless to health and objectionable on esthetic grounds only if the fish is not canned or cured promptly after removal from the water.

The skates and rays are apparently an ancient offshoot of the shark ancestral stem. They have become flattened in adaptation to a bot-

tom-dwelling habit, the pectoral fins are developed into great lateral wings fused with the body and head, and the tail region is sometimes reduced to a mere whiplike appendage. The eyes lie on the upper, colored, sides, while the mouth and gills are on the ventral face of the body, which is practically or wholly unpigmented. This group of fishes contains some remarkable types, among them the gigantic devilfish, which reaches a breadth of about 25 feet across the wings and a weight of 10,000 pounds. Extraordinary myths have grown up around this fish; for instance, its alleged habit of picking up anchors and towing ships to sea; but its strength is ample without exaggeration, large specimens when harpooned towing heavy launches at considerable speed for hours before becoming exhausted.

Other extraordinary species are the torpedo, with electric organs capable of administering a strong shock, and the sting rays, among the most common of the coastal species, the tails of which are armed with a serrated spine several inches long, which can be driven home deeply into the flesh of an enemy. Most of the skates and rays, probably all of them, are edible, and some are highly regarded in most parts of the world, although almost neglected as food in the United States. The great wings or fins are the parts used, being left yoked together by the pelvic girdle after the head, body, and tail are cut away. The two connected wings are known as a "saddle." The flesh of the skate is white, flaky, and of excellent flavor.

"Fish stories" are notoriously untrustworthy, and the man who values his reputation is properly conservative when he relates one which is at all beyond the bounds of ordinary experience. The master of a vessel entering at New York in March, 1882, had this in mind when he reported that he had sailed for 15 miles through a sea covered with dead fish of a strange species. From an investigation immediately ordered by Professor Baird, United States Commissioner of Fisheries, it was learned that this vessel had actually passed through more than 60 miles of this marine necropolis, and from the reports of other shipmasters reaching port at about the same time, it was estimated that upward of 1,400,000,000 dead fish were distributed over an area 170 miles long and 25 miles wide, lying off the coast of Long Island and New Jersey.

The investigation disclosed further that these fish were all of a species discovered and described but three years before under the name Lopholatilus chamaeleonticeps, which for general use had been abbreviated to "tilefish." As the tilefish was at once recognized as an excellent food fish, abounding within a short distance of New York and other large markets, Professor Baird immediately instituted investigations of both scientific and economic interest, which were continued under his successor, Commissioner McDonald.

The Fisheries steamers *Albatross* and *Fish Hawk*, and the schooner *Grampus*, made a number of trips each year to the former tilefish grounds without taking a single specimen, and in the Report of the National Museum for 1889, the species was listed, provisionally, as extinct. Professor Verrill made extensive collections along the edge of the Gulf Stream, the habitat of the tilefish, in 1880, 1881 and 1882, and in the latter year had occasion to report that "One of the most peculiar facts connected with our dredging this season (1882) was the scarcity or absence of many of the species, especially crustacea, that were taken in the two previous years, in essentially the same localities and depths, in vast numbers, several thousand at a time." He was of the opinion that the disaster to the tilefish was accompanied by wholesale destruction of bottom life, and that the two were due to the same cause, the encroachment of cold waters from inshore on the bottoms formerly bathed by the Gulf Stream.

In 1889, Prof. William Libbey, in behalf of the United States Fish Commission, undertook an investigation of the physical character of the sea off the south coast of New England. He found that the Gulf Stream was "off soundings," that is, its warm waters did not touch the bottom, but in 1890 and 1891 he found that it was progressively nearer the edge of the continental platform and was able to predict that in 1892 the old tilefish grounds again would be bathed in warm Gulf Stream water, and present a favorable environment for the fish. In July of 1892 the *Grampus* proceeded to the locality, set its trawls and caught the fish. The explanation of the extraordinary occurrence of March, 1882, appears to be this:

The tilefish, like the cod, is a bottom dweller; but, unlike the cod, it is of a family accustomed to the warmer waters of the Tropics. It finds a congenial temperature where the edge of the Gulf Stream touches the sea bottom, on a slope as steep as a mountain side, and there is, therefore, but a narrow strip on which the water is neither too shallow nor too deep. The Gulf Stream is a great, warm, oceanic river flowing between banks of cold water, not fixed like the solid banks of land streams but pushed one way or the other as the path of the stream approaches or recedes from the coast. There is evidence that about the time of the decimation of the tilefish the Gulf Stream was receding, and as it moved offshore its warmth no longer reached the bottom and the fish and other animals dwelling there were left in the chilly waters which took its place. It is reasonable to suppose that being habituated to a warm and equable submarine climate they were killed by the cold wave which enveloped them.

When the warm water again touched the bottom the fish migrated from areas in which the mortality had not been so complete. Further investigations showed that the fish were gradually increasing

in numbers and about 1902 they were reestablished in the old haunts as abundantly as before the disaster.

The tilefish is a large, brilliantly colored, handsome species, of excellent food qualities, and a firmness of flesh which makes it adapted to shipment over long distances. It was unknown in the markets until October, 1915, when the Bureau of Fisheries undertook a campaign to introduce it and met with such success that over 10,000,000 pounds were sold within a year, and it has been marketed from Seattle, Washington, to Liverpool, England.

In the case of the tilefish the problem of utilization involved also that of production, and of inducing the fishermen to go out and catch it, but with many other fishes the supply is an incident to the fisheries as already prosecuted. The fish are caught, but few are eaten. This is the case with the whiting of the New England coast, which is often taken in such vast numbers as to be a burden on the fisherman and a nuisance to the neighborhood on account of the quantities of dead ones from the nets, which are thrown up by the sea on the beaches. This is an excellent fish when fresh, but unfortunately its keeping qualities are poor, and, excepting in proximity to the fisheries, it is available to the consumer only when frozen or salted. The emergency demand for fish which has arisen as a result of the war has increased the consumption of whiting, but the supply available during the summer and fall is still far from being utilized.

Another species which the fishermen have regarded as a nuisance is the sablefish of the Pacific coast. It is found in many places associated with the halibut, and its habit of taking the hooks intended for that valuable species, and its own unsalability, made it anathema to the fishermen, and their cursing was in explicit terms. Millions of pounds have been thrown back into the sea annually, while the demand for fish in some parts of the country could not be satisfied. It was not eaten, except locally, because its qualities were unknown to the public, but a campaign of publicity has corrected that condition and it is now on sale not only in the Pacific Coast States, but as far east as New York, and the fishermen are finding it a material source of profit. The name "sablefish" was sponsored by the Bureau of Fisheries at the beginning of this campaign, the fish having been known previously as black cod, although it is not a cod and is not related to the cod family by lineage, structure or edible qualities. When it was discovered and described in 1811, the only name which it bore was the barbarous one, "beshow," used by the Indians and the early settlers and fishermen in recognition of its color and with an extraordinary indifference to other characters gave it the name which it has borne until recently. So long as the fish was practically unknown and unutilized, this popular misnomer was of little real

moment, although, like all error, regrettable, but when it was about to enter more intimately into commerce and into the knowledge of the people, it became actually misleading, as the meat of the cod is dry, while that of the sablefish is rich, fat, and of different flavor, and requires other methods of cooking.

The sablefish as caught, averages about 15 pounds in weight although it grows much larger. It lives on the banks near the 100-fathom line from southern California to Alaska, being more abundant north of San Francisco. Its food consists of small fishes, crustaceans and other bottom-dwelling animals, but little information concerning its habits has become a matter of record.

There is another fish on the Pacific coast which has suffered, or perhaps it were better to say benefited, by the same sort of neglect which has been visited on the sablefish, although its habits are such that it has not been regarded by the fishermen as a nuisance. Its possibilities have been merely disregarded. This is the eulachon, related to the smelts which are highly esteemed in various parts of the world, and sometimes erroneously called "Columbia River smelt." During the winter months these little fishes appear in the mouths of coastal streams in great abundance, deposit their spawn and all, or nearly all, die. Each generation, after having provided for its successor, is completely, or almost completely, exterminated.

There are a few other species which exhibit this interesting and remarkable phenomenon, and some others show a tendency toward it. In certain of the lakes of Maine the true smelts die in large numbers after spawning, although there is nothing approaching a complete mortality of an entire generation. Studies of the Atlantic salmon have shown that a considerable proportion of the individuals of each generation die after their first spawning, but the most conspicuous examples of this catastrophic life history are found among the several species of the Pacific salmons of the genus Oncorhynchus. These large and handsome fishes have very definite life cycles of from two to four or five years according to the species, and they perish to the last fish after the first act of spawning. Many of these salmon struggle from the sea up the streams against all obstacles for hundreds—in some cases more than a thousand—of miles, until they reach their spawning grounds, and it was at one time supposed that the exhaustion caused by these stupendous exertions and the wounds suffered en route were responsible for the mortality, but it is now known that the same phenomenon occurs in streams but a few miles long. The fact seems to be that the fish meet with a sudden onset of senility. The step from full maturity and adult vigor to old age is bridged by a few weeks, while the stages of youth, adolescence and maturity are measured by years.

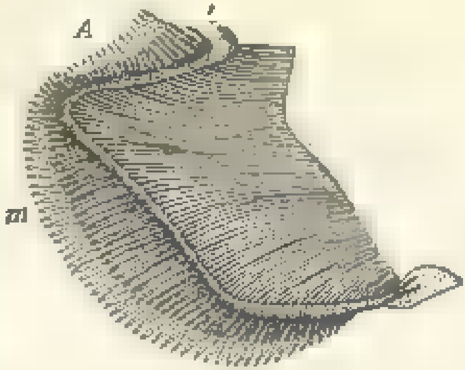
The life history of the eulachon has not been investigated, but the evidence appears to indicate that it is not very different from that of the Pacific salmons. These slender little fishes, which reach a maximum length of not much over a foot, are found from Oregon to Alaska, passing most of their life in the sea, but, as already stated, at its end running into streams to spawn. They are probably the fattest of fishes and when dried at their best a cotton wick passed through the body will yield, when lighted, an illumination comparable to that of a poor candle. This may not appear to commend them as food, but it happens that their oil has a peculiarly agreeable flavor and Doctor Jordan has described the eulachon as being "the finest food fish in the world, tender, fragrant, digestible," and others familiar with it accord it equally high praise. It is extraordinary that a fish of such fine qualities and great abundance should have remained practically unutilized, but habit and prejudice in diet are difficult to overcome. Now that animal foods of the well known kinds are insufficient for the world's needs, the eulachon should come into its own, and the Bureau of Fisheries has undertaken to tell the public about it and how it may be used.

There are many other fishes in the sea, caught by the fishermen and thrown away for lack of a market, which should be utilized. Practically all marine fishes are "good to eat" and all have about the same general nutritive qualities. Some are better than others owing to superior flavor, better keeping qualities or fewer bones, but many of the neglected kinds are as good or better than those which are eaten. Besides those previously mentioned, there are sea robins, black groupers, black drums, the so-called rock cod of the Pacific coast, and many others which are caught in large numbers and mostly thrown away or used for less important purposes than as food.

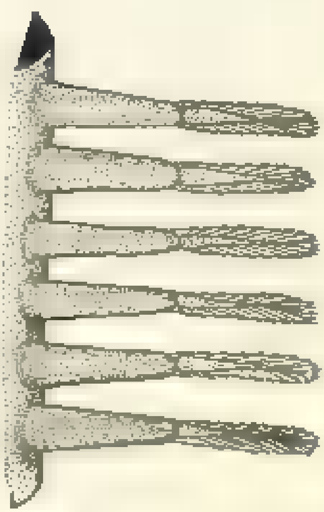
There is much talk of "speeding up" our fisheries by increasing their activities. That is a laudable purpose when the world needs food, but difficult of accomplishment when labor, vessels, and materials are hard to get, and when all are needed in the world's other constructive and destructive activities. By all means let us do it if possible, but if the kinds of fish now caught and thrown away were all utilized for food, the fisheries would be "sped" without seriously competing with other essential things.

As a striking case in point it is appropriate to mention the recently developed demand for whale meat. The shore whale fisheries of the Pacific coast have been prosecuted for a number of years for the yield of oil and some minor products. The flesh of the whales caught, when not used for fertilizer, was thrown away, but during 1917 it was placed on the market for food purposes and its excellence created a demand which the supply was not able to satisfy. The

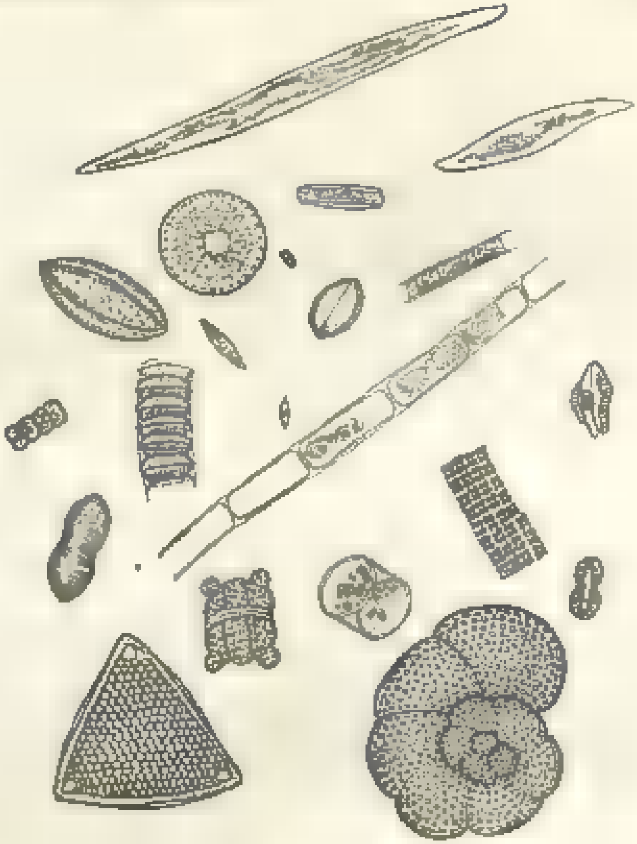
Bureau of Fisheries has done the same thing with other sea foods, and it can be done again with most of those which are now neglected, but it will require the enlightened cooperation of the fishermen and the fish trade and a willingness on the part of the public to forsake prejudice and learn to ask for and to eat other fishes than those which were known to our parents. With such cooperation the marketable yield of the fisheries can be vastly increased with but little increase in fishing activities.



A. GILL OF THE MENHADEN.



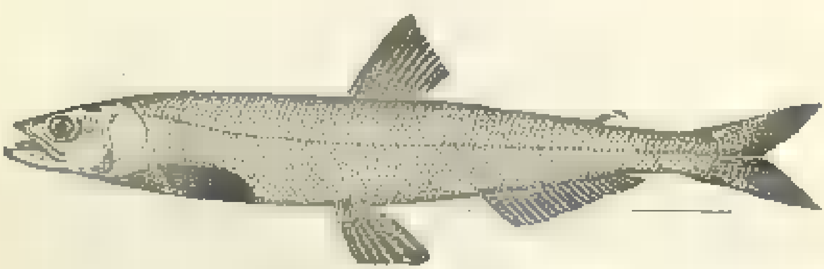
B. PARTS OF SIX GILL RAKERS OF THE MENHADEN'S "FILTER" A.



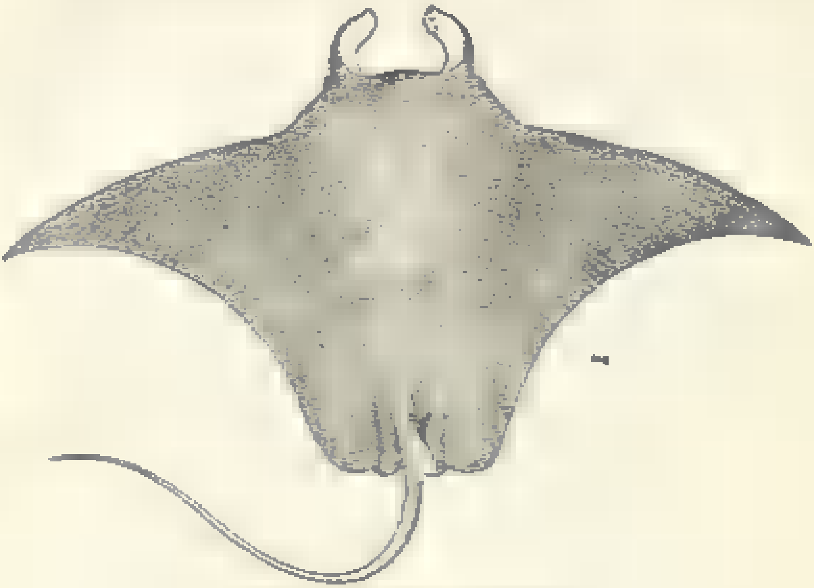
FOOD OF THE MENHADEN.

SEA MUSSEL (MYTILUS EDULIS).

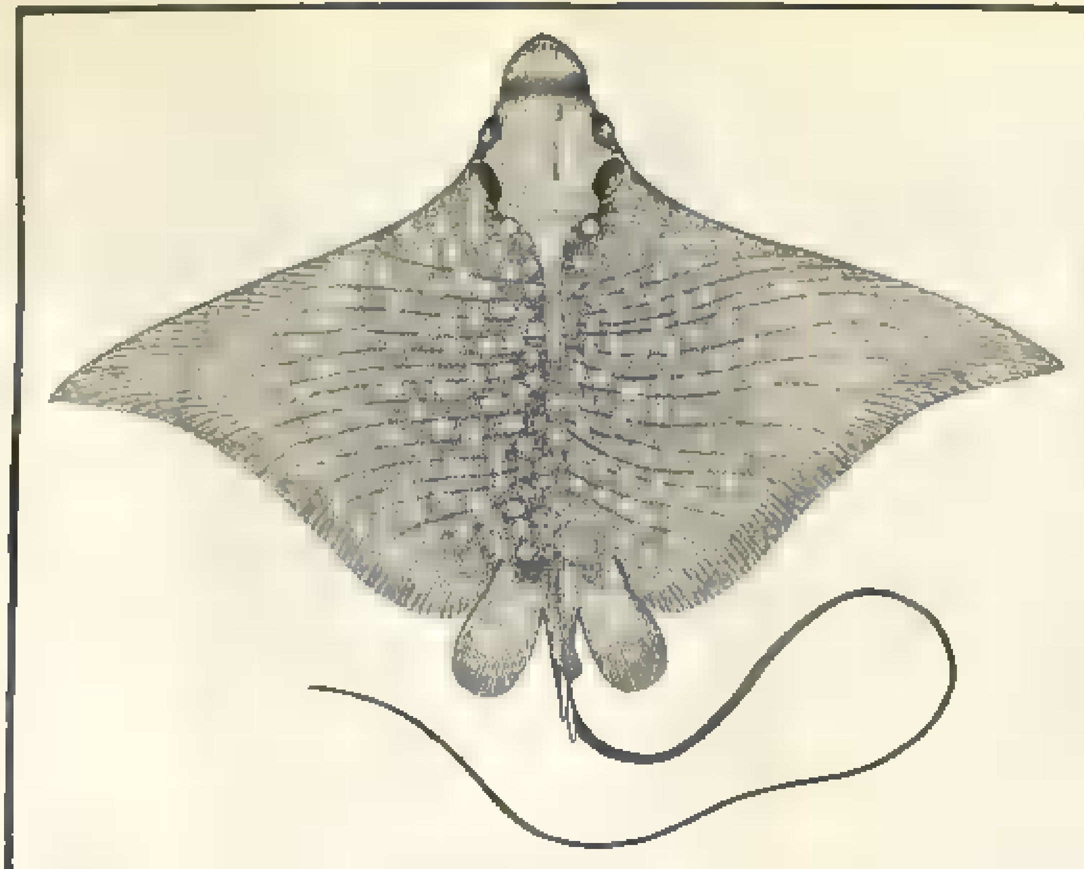
A. GRAY FISH (SQUALUS ACANTHIAS).



B. EULACHON (THALEICHTHYS PACIFICUS).



GIANT RAY (MANTA BIROSTRIS)



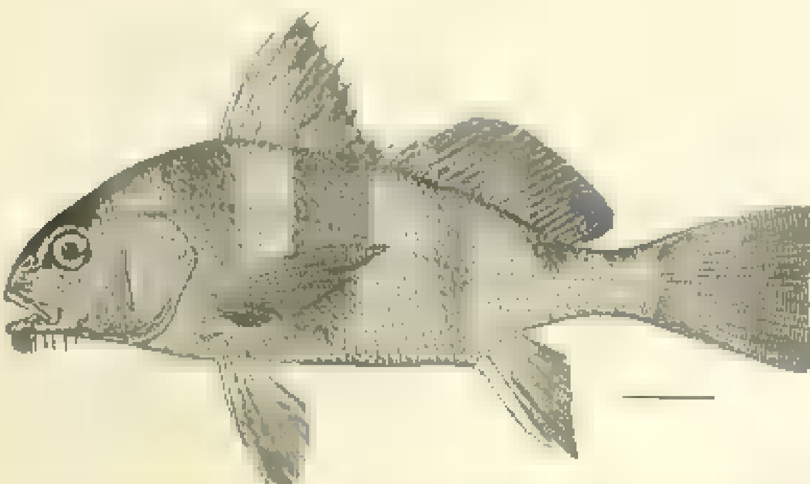
AËTOBATUS NARINARI.

Spotted Sting Ray (*Aëtobatus narinari*).

A. TILEFISH (LOPHOLATILUS CHAMAELONTICEPS).

B. WHITING (MERLUCCIUS BILINEARIS).

A. SABLEFISH (ANOPLOPOMA FIMBRIA).



B. BLACK DRUMFISH (POGONIAS CHROMIS).

OJIBWAY HABITATIONS AND OTHER STRUCTURES.

By David I. Bushnell, Jr.

(With 6 plates.)

A century or more ago Indian wigwams were numerous in the country west of the Alleghenies, and only a few generations had elapsed since villages of the Algonquian tribes were scattered throughout the vast region from the Atlantic to the Mississippi and beyond. But with the coming of the Jamestown colonists in 1607, and the arrival a few years later of the Pilgrims on the northern coast, began the gradual withdrawal of the native tribes. Some became absorbed by the stronger, more numerous bodies, others moved westward, later to fall before their native enemies, or to succumb to the encroachment of European, and later of American, settlements. Thus gradually, though surely, the native structures disappeared before the advancing civilization, and although a generation ago many were still to be seen in northern Wisconsin and Minnesota few now remain, and probably within another generation all will have vanished.

The habitations of the northern and central Algonquian tribes, from the coast westward to and including the greater part of the Ojibway, appear to have been quite similar. The dome-shaped wigwam predominated. The principal differences between those erected in widely separated areas seem to have been in the kind of bark or mats with which they were covered. The general appearance of the small settlements was probably the same in all parts of the country; therefore the last remaining villages and camps of the Ojibway may be accepted as typical of all that once existed in the upper Mississippi Valley, in the vicinity of the Great Lakes and the valley of the Ohio, and eastward to the coast.

Nearly four centuries have elapsed since this form of habitation was first mentioned. Verrazzano in the year 1524 passed northward along the Atlantic coast, stopping at many widely separated villages, one of which was evidently near the eastern end of Long Island. This was undoubtedly an Algonquian settlement, and may have been a village of the Shinnecock near Montauk Point. There "we saw

their dwellings, which are of a circular form, of about ten or twelve paces in circumference, made of logs split in halves * * * and covered with roofs of straw, nicely put on, which protect them from wind and rain. * * * They change their habitations from place to place as circumstances of situation and season may require; this is easily done, as they have only to take with them their mats, and they have other houses prepared at once. The father and the whole family dwell together in one house in great numbers; in some we saw twenty-five or thirty persons."[1] Another version of the report describes the habitations as having been "made with half circles of timber," which would clearly indicate the circular, dome-shaped wigwam, formed by bending and securing small saplings or branches, and covering the frame with mats made of rushes, or sheets of bark, or possibly with both, as is done by the Ojibway. And later it will be shown how perfectly this early description will apply to the present-day Ojibway wigwam as erected in the southern part of their country.

The habitations of the native tribes of tidewater Virginia, tribes which constituted the Powhatan confederacy of early colonial days, as well as the extreme southern members of the Algonquian family whose villages on the mainland and islands of northeastern North Carolina were discovered by the first expedition sent out by Sir Walter Raleigh in 1584, were rather different from many found farther north. The sketches of the towns of Pomeiooc and Secota, made by White, who was a member of the second expedition, are preserved in the British Museum. These show the habitations to have been flat in front and rear, with an arbor-shaped roof merging into the side walls. They are also shown to have been somewhat longer in proportion to their width than were the dome-roofed structures. However, it is not probable that in any locality one form of habitation was used to the exclusion of all others.

During the years 1899 and 1900 the writer made several trips to northern and central Minnesota, first going northward from Ely, across the international boundary, to visit the large lakes on Hunters Island, later in the year making a short trip to Cass Lake, and the following spring examining the entire shore line of Mille Lac, camping at the Ojibway village of Sagawa'mick on the south shore of that magnificent body of water. Many photographs were made, including some of the various forms of habitation, and of other structures, then erected by the Ojibway, and as these are among the last to stand it is desirable to record their form and appearance.

On October 5, 1899, we were encamped near the south shore of Basswood Lake, but whether north or south of the international

[1] Cogswell, J. G. The Voyage of Verrazzano. In collections of the New York Hist. Soc. Second series, Vol. 1, 1841.

boundary we did not know, when the sound of a drum was distinctly heard coming from an Ojibway camp far down the opposite shore, some 5 miles away. Later in the day the writer, accompanied by one Indian and using a light birch-bark canoe, crossed the lake and after passing among many small islands reached the scene of the dance which was being held on rising ground immediately in the rear of a group of five wigwams. Of these, two were of the long, oval form, the *ginon' dawan*, the others were conical and smaller, the *na' sawaö' gan* of the Ojibway. On the rocky shore were 12 birch-bark canoes, 2 of which were decorated, 1 having seven vermilion spots on each side extending from end to end, the other having a blue cross painted on either side of each end, four in all. Less than 100 yards eastward from the wigwams was a small cemetery, the graves covered with heavy hewn logs, and near many were upright poles, 4 to 6 feet in height, to the top of which were attached narrow strips of cloth, some red, others white.

The site chosen for the ceremony was immediately behind the group of wigwams, away from the lake shore. The space had first been cleared of brush and grass, then a circle of pine and cedar boughs had been arranged. The diameter of the circle was about 40 feet, the height of the boughs 2 or 3 feet. The only opening faced the south and just outside the circle, toward the east, stood a tamarack pole some 12 or 15 feet in height and surmounted by a roughly carved wooden figure of a kingfisher, the totem of the principal man of the settlement. In the center of the circle was a large drum, surrounded by several men and boys who beat it in unison. Within the circle a single row of mats had been spread on the ground touching the circle of boughs. These served as seats, the men being on the western and the women and children on the eastern side. A large pine log placed on the ground against the boughs, northeast of the drum, formed a seat occupied by Ahgishkemunsit—the Kingfisher—and several of the older men.

Standing at the entrance was a young man who acted as master of ceremonies and who held a piece of buckskin, about 2 feet in width and 3 in length, covered on one side with eagle feathers and with long narrow strips of skin attached to two corners. All being in readiness the men and boys began beating the drum and the man carrying the buckskin apron, or *chippeesung*, entered the circle, passed from left to right and stopped before the first woman to the left of Ahgishkemunsit. She jumped up and assisted in fastening the apron about her waist, allowing it to hang down behind. Two men facing her arose and immediately the three began dancing but never touching one another. They passed four times around the drum, then stopped before their respective seats. The woman next

the one who had danced assisted in removing the *chippeesung* and carried it to its keeper at the entrance, then returned to her seat. She was the next to dance, and so they continued, always moving from left to right, with their right hands nearer the drum. The dance being over for the time, two large kettles were opened and their steaming contents distributed to all within the circle. The kettles were taken from one of the large wigwams and placed on a mat in front of the log seat. The majority had sheets of birch bark; a few had old tin plates, upon which they were served. First to receive his portion was the Kingfisher; after him the men, boys, women, and young children in the order named. One of the kettles contained moose meat and wild rice boiled together; the other held a stew of dried blueberries. Thus we left them, in the gathering dusk, and returned to our camp across the lake.[1]

Two days later we again stopped at the camp but a great change had taken place since our previous visit. The annual gathering which was at that time being celebrated had terminated and many of the participants had departed for their homes on other lakes. Only two wigwams and the bare frame of another remained. The settlement as it appeared that morning when being approached in a canoe is shown in plate 1, figure 1. On the extreme left in the picture is a moose hide on an upright frame; just below it is an upturned canoe on the rocky margin of the lake. The bare frame of a conical wigwam is visible and just beyond it a complete structure of the same form. To the right of the large wigwam are several upright posts with others resting above them in a horizontal position. Between these poles were to be suspended a number of white fish which had just been taken in nets. Cords formed of twisted basswood bark were passed through the tails of the fish; the ends of the cords were then attached to the parallel horizontal poles; the fish thus hung heads downward and during the long cold season would remain frozen until required for food. Another canoe is drawn up on the shore near the poles, and the path leading from it is visible.

The two wigwams belonged to types found far northward to the subarctic region but which never occurred south of central Minnesota. Both were formed of long, continuous strips of birch bark, or of several shorter pieces sewed together to make one of the desired length, known to the Ojibway as *wiguassupakwei*, placed over a frame of straight saplings with others laid on the outside to hold the bark strips in place. The inner surface of the bark served as the outside of the structure and this is likewise true when it is used in the construction of canoes.

[1] Bushnell, jr., D. I. An Ojibway Ceremony. American Anthropologist. Vol. 7, No. 1, January-March, 1905. pp. 69–73.

A nearer view of the conical wigwam, the *na' sawaō' gan*, is given in plate 1, figure 2. This was occupied by one family and was similar to another described a few years before:

> The strips of birch bark are laid loosely on, and there are great chinks everywhere through which one can put his hand, and there is the open top. The family sit round the fire in a circle, on rush mats made by the women from rushes which grow in the lakes. * * * On approaching a wigwam, the custom is to raise the blanket which hangs over the doorway and go in without asking permission or knock as with us. * * * If the inmates look on the newcomer with favor they say when he raises the blanket door and looks in, "Nind abimin, nind abimin (we are at home, we are at home)," which is a welcome, though nothing is thought on either side if silence is preserved. * * * Around the fire in the center, and at a distance of perhaps 2 feet from it, are placed sticks as large as one's arm, in a square form, guarding the fire; and it is a matter of etiquette not to put one's feet nearer the fire than that boundary. One or more pots or kettles are hung over the fire on the crotch of a sapling. In the sides of the wigwam are stowed all clothing, food, cooking utensils, and other property of the family. * * * When one has been traveling all day through the virgin forest, in a temperature far below zero, and has not seen a house nor a human being and knows not where or how he is to pass the night, it is the most comforting sight in the whole world to see the glowing column of light from the top of the wigwam of some wandering family out hunting, and to look in and see that happy group bathed in the light and warmth of the life-giving fire. * * * and no one, Ojibway or white, is ever refused admission; on the contrary, they are made heartily welcome, as long as there is an inch of space.[1]

Other views of the large wigwam, the *ginon' dawan*, shown in figure 1, plate 1, are given in plate 2, figures 1 and 2. It was about 18 feet in length and between 8 and 9 feet in width. There were two entrances, one at each end, each covered with a blanket as in plate 2, figure 2. This was occupied by the family of Ahgishkemunsit, the Kingfisher, at that time about 60 years of age and a man of influence among the northern Ojibway. As will be seen in the photograph, the large wigwam had a ridgepole extending between the two groups of poles which were arranged at the ends of the structure. Other poles resting against the ridgepole formed the sloping supports upon which the long strips of bark were placed. Inside four small fires burned on the ground along the median line. Rush mats were spread near the walls to serve as seats during the day and sleeping places at night. Various bunches of herbs, small bags, baskets, and other articles hung from the poles. A large birch-bark *mokak* stood in one corner and on the opposite side was the drum which had occupied the center of the dance circle two days before. Women were engaged in making moccasins, children were playing about, and the men, in-

[1] Gilfillan, Rev. J. A. The Ojibways in Minnesota. In collection of the Minn. Hist. Soc., Vol. IX, St. Paul, 1901, pp. 55–128. Having lived for more than 25 years among the northern Ojibway, beginning in 1873, few were more familiar with the manners and customs of the people, or could write with greater certainty and feeling.

cluding Abgishkemunsit, were sitting near the fires smoking their black stone pipes.

Looking at this small camp as we approached it in canoes, it was easy to visualize the village at Sandy Lake as it stood some years before.

> A collection of wigwams, some conical and some oval in shape like gypsies' tents, were grouped confusedly upon the sandy beach, between which were suspended either fishing nets, or lines from which hung rows of fish being cured. * * * A few canoes were fishing off the village; a number more lay upturned upon the edge of the lake, where a knot of persons were collected, evidently watching with some interest so unusual an arrival as a large canoe from the eastern shore with eight paddles.[1]

The habitations just mentioned differed greatly from those found in other parts of the Ojibway country. They were necessarily restricted to the region of large birch trees, where wide strips of bark could be easily obtained. Southward the dome-shaped wigwam, the *wagino' gan*, was used, this being the type of habitation which formerly stood throughout the Algonquian territory eastward to the Atlantic. An example of the latter form is given in figure 6, this having been one of the group of 10 or 12 similar structures which constituted the village of Na' ha' shing, on the south shore of Mille Lac during the month of May, 1900. These wigwams extended in a single line—plate 3, figure 1—parallel with the lake shore and distant about 200 feet from the water. Some two years before the virgin pine on the south shore of the lake had been cut away and in 1900 few large trees remained, although the majority of the maples had been spared. Until the destruction of the timber the native villages had stood protected in the midst of the great forests.

The wigwam shown in plate 3, figure 2, was roughly rectangular in form, about 14 feet square and [illegible] feet high in the center. The framework was formed of saplings, seldom more than 2 inches in diameter, one end set firmly in the ground and the other bent over and attached to similar pieces coming from the opposite side. Other small branches and saplings had been securely attached to these in a horizontal position about 2 feet apart, making a rigid structure. Thus a dome-shaped framework was erected over which were spread rush mats and strips of bark. Instances are known where the entire frame was covered with elm or cedar bark. The covering was held in place by cords which passed over the top and were attached to stones which hung suspended on either side, or some were tied to poles which hung horizontally near the ground, as shown in plate 3, figure 2. The fire was made inside on the ground near the center of the floor space, although in good weather the cooking was done outside the wigwam. The interior was dark and depressing, the walls

[1] Oliphant, L. Minnesota and the Far West, Edinburgh and London, 1855, pp. 193–194.

smoked from many fires and the floors often damp. In the better structures of this type a second row of mats was placed on the inside of the frame, and when held firmly in place added greatly to the warmth and comfort of the interior. Similar mats were open on the ground and the simple utensils hung from the frame. Little else was to be seen within.

The Mide' lodge, often a hundred feet or more in length, was in reality an elongated example of the *wagino' gan*. The frame was similarly constructed but often the covering was of a more temporary nature, boughs being occasionally used. The frame, however, would be allowed to stand from year to year, to be covered when necessary.

No season of the year was anticipated with more genuine pleasure by the Ojibway than early spring, when the maple sap began to run. Then they would leave their winter encampments and move to their sugar camps where, during the following weeks, vast quantities of sugar would be made, much of it being preserved for future use. The sap was evaporated, seldom boiled, in large kettles suspended over fires within houses especially prepared and retained for this purpose. Such a building is shown in plate 4, figure 1. It stood on the south shore of Mille Lac, on Mozomana Point, and had been used just before the photograph was made in May, 1900. This was known to the Ojibway as *I' ckigami' sige' wigumi' ig*, or "house where the water is evaporated from the sap." The framework was heavy, the covering was of elm bark. One large opening was arranged in the top as an outlet for the smoke. In the rear and to the left of this may be seen the frame of a dome-shaped wigwam, the covering having been removed. This had probably been occupied during the period of sugar making.

In plate 4, figure 2, a similar elm bark covered lodge is shown. This stood in the village of Sagawa' mick, the principal settlement on the shore of Mille Lac, and was used as a habitation, being known to the Ojibway as a *gaka' gaogan'*. Immediately in front of the entrance was an oval-topped arbor, covered with elm bark. The moccasin game was being played by the group in the foreground. Several similar buildings stood in the village, but no other arbor was seen. In some respects this structure resembles and suggests the houses of the Iroquois, and this is likewise true of the Mide' lodge which recalls their long-house. Both forms appear to have been unknown to the southern Algonquian tribes.

A view of the eastern part of the village of Sagawa' mick is given in plate 5. Frames of several wigwams are visible; others with their mat and bark coverings are in the distance. This was the site of one of the large villages of the Mdewakanton Sioux who formerly

claimed and occupied this region, and who were driven southward by the Ojibway during the first half of the eighteenth century. A large group of burial mounds marks the site of this ancient settlement; these are recognized by the Ojibway to have been the work of the Sioux and to have been erected over the remains of their dead, and it is of interest to know that the summits of the mounds were utilized as places of burial by newcomers. In the view of Sagawa' mick many Indians are shown standing on the summit of a mound; on the same mound are visible logs covering recent graves. The photograph was made from the top of another mound. The region is one of much interest, for less than 5 miles away stood the village where Father Hennepin, in 1680, was held captive by the Sioux. The site was discovered and identified in 1900.

The small sweat house, plate 6, figure 1, stood on the margin of the lake at Sagawa' mick. The frame of saplings was covered with several old blankets. The ground within was strewn with balsam boughs and in the center was a small heap of sand. Stones about 6 inches in diameter were heated in the fire just outside. The person to receive the treatment would enter the inclosure, several heated stones being placed on the heap of sand and a quantity of water provided. The blankets were then closely wrapped about the frame so as to retain the heat and vapor. The one within would then sprinkle water over the hot stones and steam would soon fill the small space. After a given time the person would rush from the house and plunge into the cold waters of the lake. Similar baths have been in use since the earliest times and the custom was followed by all the eastern tribes. A description of a sweat house used by the Iroquois in the northern part of New York during the year 1652 would easily apply to the one employed at Mille Lac two and one-half centuries later.

> In this place our wild people sweated after the maner following: first heated stones till they weare red as fire, then they made a lautherne w^th small sticks, then stearing the place w^th deale trees, saving a place in the middle whereinto they put the stoanes, and covered the place w^th severall covers, then striped themselves naked, went into it. They made a noise as if y^e devil weare there; after they being there for an houre they came out of the watter, and then throwing one another into the watter, I thought veryly they weare insensed. It is their usual Custome.[1]

The most interesting of the Mille Lac structures remains to be mentioned, the council house, which in May, 1900, was still standing in the dense woods, on high ground near the southwestern corner of the lake, about 1 mile north of the outlet and 200 yards from the shore. Two years later it had disappeared and no trace of it could be found. As shown in plate 6, figure 2, it was oriented with its sides facing the cardinal points, about 20 feet square, with walls

[1] Radisson. Voyages of Peter Esprit Radisson. Prince Society, Boston, 1885. p. 28.

6 feet in height and the peak of the roof twice that distance above the ground. The heavy frame was covered with large sheets of elm bark which had evidently been renewed from time to time during preceding years. No traces of seats remained, and grass was again growing on the ground which had served as the floor. This was the scene of the treaty of October 5, 1889, between the Ojibway of Mille Lac and the United States Government, which proved so disastrous to the former.

Such were the native structures of the Ojibway, and although variations would undoubtedly have been found in different parts of their country, the general forms remained the same.

1. OJIBWAY SETTLEMENT ON SHORE OF BASSWOOD LAKE.

2. CONICAL WIGWAM, NÁSAWAÓGAN, SHOWN IN FIGURE 1 ABOVE.

1. LONG WIGWAM, GINOŃDAWAN, SHOWN IN PLATE 1, FIGURE 1.

2. ANOTHER VIEW OF THE LONG WIGWAM, SHOWING ONE ENTRANCE.

1. VILLAGE OF NÁHÁSHING, SOUTH SHORE OF MILLE LAC, MAY, 1900.

2. WIGWAM, WAGINÓGAN, AT VILLAGE OF NÁHÁSHING.

1. SUGAR LODGE, SOUTH SHORE OF MILLE LAC, MAY, 1900.

2. HABITATION AT VILLAGE OF SAGAWÁMICK MILLE LAC, MAY, 1900.

VIEW OF THE EASTERN PART [illegible] THE OJIBWAY VILLAGE OF SAGAWÁMICK.

1. SWEAT HOUSE AT SAGAWÁMICK, MAY, 1900.

2. OLD COUNCIL HOUSE ON SOUTHWEST SHORE OF MILLE LAC, MAY, 1900.

NATIONAL WORK AT THE BRITISH MUSEUM—MUSEUMS AND ADVANCEMENT OF LEARNING.[1]

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I. NATIONAL WORK AT THE NATURAL HISTORY MUSEUM.

Shortly after the beginning of the war, as part of an attempt to clarify our views as to the position that museum workers might adopt, we published an article on "Museums and National Service" (Museums Journal, Oct., 1914, pp. 121–127). This dealt mainly with the work of the natural history departments of the British Museum in the years immediately preceding the war. The recent publication of the British Museum "Return" for 1916 suggested that it was time to publish a similar article, showing how all this national work has continued in spite of many difficulties and, more particularly, how it has been utilised for the prosecution of the war. This article was indeed being prepared when recent events gave direful proof of the need for more widespread information concerning the activities of the Natural History Museum. A brief selection was therefore published in the Times (Jan. 5th, 1918). The Executive Committee of the Museums Association feels, however, that it will be well to have a statement of this kind issued in the more permanent form afforded by the Museums Journal, so that it may be brought to the notice of all museum committees, and may assist them to appreciate one aspect of museum work perhaps more fully than has been possible for them hitherto. For it must not be thought that this is a matter with which other museums have no concern. Quite apart from the fact that much useful work of the same character is being conducted in many a museum, it must be remembered that "we are all members of one body," and that, as an attack upon one is an attack upon all, so also the benefit of one museum is in the end the benefit of the rest. Happily, we are not competitors but cooperators and colleagues.

The writing of the desired article is not altogether easy. The bluebooks are not lavish of such information, and what is given is in too condensed a form for general consumption. Without the

[1] Reprinted, by permission, from the Museums Journal, vol. 17, pp. 120–126, February, 1918, and pp. 161–169, May, 1918.

elucidation kindly furnished by members of the staff it would have been impossible to produce an intelligible account. It is a great pity that this should be so. Doubtless the authorities recognise that bluebooks are not read, even by the official circles for whom they are intended, and they have therefore not objected to a reduction of size by one-half, enforced for economic reasons. This only makes it the more advisable that there should be some way of reaching the public—some "Museum Magazine," under official auspices, but without the cumbrousness and reserve characteristic of all officialdom.

Another difficulty on the present occasion is that many of the more important and interesting facts cannot yet be revealed. And still a third difficulty arises from the circumstances that the officers of the museum themselves may be ignorant of the services rendered by the collections. Many an enquirer after some rare mineral, some piece of geological information, or the name of some plant or animal does not divulge the object of his enquiries; his errand may be connected with munitions, with the medical service, or with field operations. For him the museum is as a dictionary; an indispensable aid, but not a confidant. The credit for his research goes to the branch of the service for which he is working, and the museum is not mentioned. A notable instance has just occurred. Those who have read Mr. Balfour's correspondence with the Netherlands Government on the subject of materials used by the Germans in their cement field works may have observed a reference to determinations by certain geological establishments. The Natural History Museum was not mentioned; yet it is in the mineral department of that museum, and there alone, that the rock specimens are preserved which rendered possible any accurate determination of the source whence the enemy derived his materials. There alone, too, it is that our metallurgists can examine the compound used by Austria in the manufacture of her high-grade steel. There alone are to be found examples of numerous minerals that are proving daily of the utmost value to investigators of urgent war problems. Though help of this kind has been rendered since the beginning of the war, no hint of it is found in the Return, nor, for fear of the censor, can a fuller statement be given here. But it is only right to give these few illustrations, because, to read the bluebooks, you would suppose that the staff of the mineral department had been quietly arranging zeolites, measuring gemstones, and studying meteorites, undisturbed by the world conflagration.

A similar inference might be drawn from the annual reports of the keeper of geology, for the ordinary reader does not immediately seize the connection between, say, the Piltdown man and national defense: he gapes at the *monstra horrenda informia* of the palaeontological galleries without attaching to them the smallest practical im-

portance. Mining engineers, indeed, and other practicians of applied science know that the precise specific determination of a fossil may often decide an expenditure of thousands of pounds. Not long ago the seekers after potash in a hitherto unworked region, desirous of correlating the rocks beneath them with those of a neighboring district, submitted fossiliferous cores from their borings. It was a fish scale and some fragmentary heart urchins that enabled the experts on such fossils to send an answer. In like manner the department has been able to aid the military authorities in Cyprus over the water supply. Those who, on behalf of the Government, are now investigating the constitution of coal find at this museum alone the large collections of fossil plants that are constantly required for reference. An obscure fact of palaeontology may confirm or rebut a theory raised on chemical evidence; a museum preparation will show that the characters of the older coals can not be due, as was suggested, to any larger amount of woody substance in the plants from which they were formed; the bituminous nature of a certain seam can no longer be ascribed to a preponderance of moss when sections in the department prove coniferous wood to be the main constituent. The detailed study of fossil shells sent from Trinidad has enabled a palaeontologist of the museum to throw light on the succession of strata in that island, and thus to facilitate the prospecting for oil-bearing deposits. These and other instances serve to show that in palaeontology as in other sciences no branch can be disregarded as too remote from actuality to have any bearing on the world of men.

The bearing of botany, on the other hand, is obvious, so obvious that the keeper of the department makes but the barest reference to the information constantly supplied to official inquirers on matters connected with the war. We are permitted to mention a few examples. At Malta the material of the army tents was being destroyed by a fungus, with a loss to the Government of enormous sums. The fungus was identified in the herbarium, and a careful study of its growth on canvas treated in various ways led to the discovery of a complete remedy. Remedies have also been suggested for another fungus which destroys the envelopes of airships. The selection of timbers appropriate to various special purposes, such as the different parts of aeroplanes, is a subject on which the department, thanks to its collection of samples from all parts of the world, has been able to render invaluable aid. Here, too, the inspectors who have to pass the wood study in prepared specimens the appearance of the diseases to which each kind is liable. A different form of study was presented by some fodder sent from a veterinary camp, where it had to all appearance disagreed with the horses. Examination of the sample revealed an extraordinary composition but no actually poisonous ingredient. Other inquiries have related to the use and

source of supply of sphagnum moss for surgical dressings, seaweeds and fungi as food, seaweeds as sources of iodin and of potash for manures, lichens for use as dyes. The damage caused by molds and fungi to foodstuffs has produced a large crop of inquiries from all quarters, including local food committees. Allotment holders also have recognized the help that they can obtain from this department in the detection and prevention of plant diseases. To give details would be wearisome. It is enough to quote the words of a weighty letter which Messrs. Sutton & Sons, of the Royal Seed Establishment, Reading, addressed to The Times (Jan. 7):

> The unremitting toil and labors of the staff in the pursuit of science, in order that its secrets, when won, may be utilized for increasing the fertility of the soil and for safeguarding the crops upon which we depend from the ravages of insect pests and fungoid diseases, are of inestimable value to the country and Empire.

We pass to the work of the zoological department. The scarcity of the world's food supply is causing attention to be paid to the suggestion that we should avail ourselves of whale meat. For some years past the keeper of the department has been collecting information as to the numbers of whales and the geographical distribution of the various kinds. Any regulations, national or international, for the capture and killing of these animals must be based on the knowledge thus accumulated. Reports have already been furnished to the Colonial Office on this subject, as well as on the hunting of elephant seals in south Georgia. It is of significance that in the last-mentioned region the whale fishery, which is as yet unregulated, has resulted in a great decrease in the numbers of humpback whales, whereas under the ordinance of 1909, regulating the sealing industry, the number of elephant seals shows no decrease, although over 3,000 have been killed each year.

The protection of birds and wild mammals is another subject for international agreement and one of great economic importance for our scattered dominions. In dealing with it the Colonial Office frequently refers to the museum for information and advice. Reports have been made on the introduction of reindeer and other animals into south Georgia. The food value of the eggs of wild birds is also under active investigation.

"All work," truly says the bluebook, "connected with the conservation and arrangement of the collection of fishes may be regarded as of potential economic importance." Officers of the board of agriculture and fisheries, with other students of fishery questions, find in the national collections material for their researches. A commercial fishing company, which proposed to exploit a new region, took the sensible step of first making a collection of the fishes and crustaceans

found there and submitting it to the Natural History Museum for an accurate report. Government departments have also been furnished with reports on the poisonous fishes of the West Indies, on the various kinds of fish preserved as "sardines," and on the lobsters of the cape. Brands of tinned "lobster" have been examined for the London Chamber of Commerce, sometimes with curious results, for one such brand was found to consist of the leg muscles of a large Japanese crab. Crustaceans have also been known to damage telegraph cables and to transmit disease, while the well-known barnacles are the worst foulers of ship bottoms. In all these cases the information and advice asked for have been given.

The presence of our armies in Egypt has caused a large number of enquiries to be sent to the zoological department, and most of these relate to Mollusca. The flat-worm, generally called *Bilharzia*, which infests the waters of Egypt and produces the irritating disease known as bilharziosis, passes part of its life in the bodies of various fresh-water snails and bivalve shellfish. Several of these have been examined and reported on for the military medical commission in Egypt and the Wellcome bureau, Khartoum. The subject is illustrated by a special exhibit in the central hall. In Egypt also a snail has proved an agricultural pest, in Jamaica a slug devastates rubber plantations, in other distant lands molluscs transmit disease or effect material damage. But it is to the Natural History Museum that all the sufferers come for help and advice.

Mites, ticks, harvesters, and the like are always with us, but their dangerous character has been accentuated by the war. Among those on which advice and information have been given to the military authorities are the Itch mite, mites that damaged stored oats in Flanders and stored corn in Colombia, mites that caused parasitic mange in horses, and one suspected of transmitting anthrax in camels at Aden. Poultry, sheep, ostriches, human beings, vegetation, and furniture are all liable to attacks by mites, and frequent are the appeals to the Natural History Museum from all parts of the world. The same may be said of the various unpleasant animals known as parasitic worms.

Of all the departments, the entomological is probably of greatest economic importance. Insects are carriers of disease to human beings, animals, and plants; they destroy our crops, our food stores, and our clothing; even solid structures are stealthily attacked by them and fall without warning into decay. Against this host of enemies the entomologists of the country are mobilized and their headquarters are at the Natural History Museum. Here works the Imperial bureau of entomology, which studies insect pests from all parts of the Empire, and hands over the material received to be preserved in the

museum for future reference. The army biscuit enquiry has previously been mentioned in these pages; even those in high places have learnt from it that there is a value in the study of Micro-Lepidopetra. Indeed we are informed that the mere labour of turning over infected biscuits in time of peace cost the country £10,000 a year, which has been saved by the recommendations of this committee. The Royal Society committee on grain pests deals with the organisms that attack grain when in store and in course of shipment to this country; the loss thus caused is great, and, as in the case of biscuits, is largely due to the larvæ of Micro-Lepidoptera.

We can mention but a tithe of the matters on which this department has given useful advice: Insects attacking the envelope of airships, locust plagues, protection of telephone and telegraph apparatus in the Tropics and elsewhere, warbles on cattle, deer, and army horses, numerous cases of damage to food stores on H. M. ships and in private ownership, remedies for the cockroach in many hospitals, for body vermin on soldiers serving or in hospital, and for the rice weevil in connection with beriberi, serious ravages of the cotton worm on a plantation in Montserrat, the plague of mosquitoes in the trenches and in this country. The investigation of the last mentioned is still in progress, and specimens, accompanied by notes as to their occurrence and habits, will gladly be received by the assistant in charge.

To continue the list would be easy but wearisome. Let us bring it to a close with two facts. First, during the past year the museum was consulted by no less than fourteen Government departments. Secondly, a single day quite recently brought the following letters: An urgent request from G. H. Q. in France for lantern slides dealing with camouflage, or what naturalists call protective mimicry and coloration; a confidential enquiry from the war committee of the Royal Society, involving considerable reseach; a letter from the War Office requesting facilities for the study of Macedonian mosquitoes by an officer of the R. A. M. C.; a plea from the direction of the Y. M. C. A. for two hours' extra opening for the benefit of oversea soldiers in London.

This last enquiry may remind our readers of the great educational work performed by the exhibition galleries. Further allusion to that lies outside our present intention, which is to convey some idea of one branch of the work which, though unseen and unspoken of, is ever in progress. Important though it be, it is by no means the main work of the museum. What its relation to that main work is, we hope to show on a future occasion.

II. MUSEUMS AND THE ADVANCEMENT OF LEARNING.

> We offer no violence and spread no nets for the judgments of men, but lead them on to things themselves, and their relations; that they may view their own stores, what they have to reason about, and what they may add or procure for the common good.—*Bacon.*

Eight or nine years ago the sugar canes in a part of Mauritius were found to be suffering from the attacks of a beetle larva which ate their roots. The Government entomologist was called in aid and provisionally determined the beetle as a species of *Schizonycha*, a Lamellicorn genus characteristic of Africa and said to be represented by two species in the Madagascan region. The only remedies that suggested themselves were to dig up the root stumps and destroy the larvae and to catch the beetles on the shrubs to which they flew for their food at night. In this way the pest was to some extent kept under, but the method of attack was lengthy and involved the employment of much labour. Although more than twenty-seven million insects were thus accounted for in less than half a year, the natural rate of multiplication is so great that the area affected rapidly increased, and there was serious risk of ruin to the whole sugar industry of Mauritius.

Meanwhile the entomologist of the island had taken the prudent step of sending specimens to the British Museum for more accurate determination. Beneath the scrutiny of the specialist in Coleoptera the beetle proved to belong not to the Old World *Schizonycha* but to the American genus *Phytalus*. Of the actual species, however, no description or record could be found. Search through the vast collections of the entomological department eventually brought to light three specimens labeled "Trinidad." This was evidence that the species occurred in the West Indies, though unnoticed by the entomologists of those islands. The latter fact indicated that it could not be causing so much damage to the sugar canes in its native home. Therefore the next step was to track it down so as to discover its natural conditions of life and, above all, what served to keep it in check. A skilled entomologist who was visiting the West Indies was entrusted with specimens from Mauritius and eventually found both beetle and larva at the roots of cane stumps in Barbados. How, then, is it that the sugar crop of Barbados has not suffered from the attack of this larva to a noticeable extent? This depends on two natural enemies. One of these is the so-called "blackbird" (*Quiscalus*), which follows the workmen when rooting up the cane stumps and eats the larvae. It cannot, however, reach the larvae underground. The other enemy, though less conspicuous, is more successful. Attached to one of the larvae brought back from Bar-

bados to the British Museum in spirit there was found a tiny grub. Its appearance and the manner of its attachment suggested that it belonged to one of the Scoliidae, those Solitary Wasps which paralyse Lamellicorn larvae so that they may form food for their own young—an operation well known to us all from the account by Fabre. Further research proved the grub to be the larva of a species of *Tiphia*, a Scoliid common in Barbados, though its economic importance had not been realised. An allied species of Scoliid exists in Mauritius but has not attacked the invader, which being thus quit of its original enemies has multiplied to the enormous extent previously described.

The *Phytalus* larva had no doubt been introduced into Mauritius with some cane cuttings imported from the West Indies a few years before. It now became an important matter to introduce the Barbados *Tiphia*. This was less easy, for the voyage is a long one; the insects died on the way, and more than one attempt had to be made before success was finally achieved. The wasp is now established in Mauritius and has begun to spread, so that the future of the sugar plantations is assured.[1]

I have recounted this romance of modern science at some length, not because of its genuine interest nor because of the large property at stake, but because it shows with unquestionable clearness the precise part that should be played by a museum in all enquiries such as those mentioned in the article on National Work at the Natural History Museum (Museums Journal, XVII, pp. 120–125, February, 1918) and indeed can only be played by a museum with its great collections and its staff of specialists. For, note these points: Until the insect was accurately determined no successful remedy could be suggested. The insect could not be determined by the very capable entomologist of Mauritius in the absence of the necessary collections for comparison. Indeed, since the species had never been described, it was possible to run it to earth only by means of the great collection that has been accumulating for over a century at the British Museum. Although the museum specimens were not actually named, still they were properly arranged in their correct genus and family, so that the specialist capable of determining the genus of the Mauritian specimens was able to make his comparison without ransacking the whole insect collection. Finally the museum specimens retained their original locality label. The suggestion that the larva might have been imported from America was made as soon as the genus was correctly identified, but the Mauritian authorities regarded it as quite improbable. It was the actual running down of

[1] For technical details, see official report by D. d'Emmerez de Charmoy, Port Louis, Mauritius, 1912; and G. J. Arrow, Ann. Mag. Nat. Hist., April, 1912.

the species that proved the point and led to the subsequent investigation and remedy.

It would be possible to go through numbers of inquiries with a practical bearing and to show how in each case the solution of the problem depends sooner or later on the correct identification of the species involved. For this identification recourse must be had to a specialist, either employed by a museum or having access to its collections. As I write there is a lively correspondence in The Times about the fisheries of Newfoundland. In the midst of much speculation and suggestion one solid contribution is made by the assistant in charge of the fishes at the British Museum, namely, an exact list of the flat fishes found in Newfoundland waters. By this the subsequent discussion must be controlled. Or, to take a problem of medicine, we all realize by now that the health of individuals, of armies, of nations depends on a correct appreciation of mosquitoes; we know how the application of this knowledge permitted the completion of the Panama Canal and thereby greatly strengthened the position of the United States and the Allies in the present war. But do we all realize the patient collecting, sorting, and discrimination of the numerous genera and species of mosquito that paved the way for the successful attack on the diseases transmitted by them? Do we realize that our army medical officers in the different theatres of war have to learn the species of mosquito against which they are sent to fight and that they come to our great museums to acquire this knowledge?

Similar proofs of the practical importance of the most refined systematic study might be adduced from every branch of the animal and vegetable kingdoms, from their fossil as well as their recent representatives. The same holds good for the collection and systematic ordering of rocks and minerals.

Some may think that too much emphasis is here being laid on the practical or economic value of the work—on what is called applied science. They are quite right. It is an attitude that has been forced upon museum officials by the incapacity of so many of our public servants to understand the value of any science that has not an immediate practical application. It is true that these people less dimly apprehend the relation of physics and chemistry to industry and engineering, for they have the results thrust before them every moment of the day in the telephone, the electric light, the safety match, the motor car, and all those facilities which so marvelously distinguish our modern civilization from that of only a century ago. But they do not have brought to their notice the equally real though less obvious connection between that same civilization and the natural history sciences. Consequently, when protests were raised against handing over the building of the Natural History Museum to another

Government department, there were many quite rational and well-meaning people who said, "Well, what's all the fuss about? Everything must give way to getting on with the war." So it was necessary for us museum folk to explain to these genuine, if ignorant, patriots that we, too, were getting on with the war quite as much as the departments for whom we were to be ousted.

Now that the immediate danger is over, without relaxing our efforts in the national cause, we can return to an attitude that is more dignified because it is in harmony with the whole truth and not merely with that small part of it which is best adapted to catch the public eye. We can insist once more that all knowledge has its value, that "the knowledge and the power of man coincide," and that you must have science before you can apply it. This leads us to the next step in our analysis, namely, to consider the relation of museums to pure scientific research.

There are many distinguished biologists who appear to be unaware of the research that is carried on in such an establishment as the Natural History Museum, and who seem to think that the work of museum naturalists can have little to do with their own studies in morphology, genetics, experimental embryology, and all those lines along which advance has of late been so rapid and brilliant. This is a great mistake, and one from which they might have been saved had they considered more closely the history of the biological sciences, and had they realized the interdependence of all branches of science. Zoology and botany made but slow progress until there arose the great classifier, Linnaeus. Linnaeus was no "mere systematist," but the need of his time was the orderly arangement of the multitudinous collections that were flooding in from all parts of the world and the coordination of the scattered facts that had accumulated concerning the animal, vegetable, and mineral kingdoms. Until this had been done, until species had been discriminated and named, there could be no science of comparative anatomy, no discussion as to the origin of species, no stratigraphical geology, no philosophy of geographical distribution, no firmly based theory of evolution, and no science of breeding. By classifying and arranging the royal and other collections at Stockholm, the university collections at Upsala and elsewhere, Linnaeus and his followers were the first to raise museums above the curiosity-shop stage and to make them an engine of scientific advance. Here it particularly interests us to remember that it was Solander, the favorite pupil of Linnaeus, who introduced his methods into all the natural history work of the British Museum. For many a decade the need for this systematic classification continued urgent; exploration of the lands and waters of the world and of the rocks beneath its surface piled up in our museums collections that became riches only in proportion as they were worked out, de-

scribed, named, and stored in accessible order. Collections still pour in, and the same work has to go on, while the advance of knowledge ever involves revision after revision of the older classifications. Our work is never done.

Meanwhile on this foundation have arisen all those other branches of biological science, each of which in its turn has seemed to its professors to be leading the way. When I entered the ranks the laboratory zoologist contemned the museum worker; then arose the biometrician with his scorn for the strainer of sections; to-day we all are expected to walk humbly before the experimental embryologist, the oecologist, and above all the geneticist.

But we museum systematists do not intend to walk humbly. We assert that the foundation is as necessary to the building as are roof and pinnacles. What was the foundation in history remains the foundation to-day, and our colleagues ignore the fact at their peril.

The oecologist and field-naturalist probably realize more than the others how dependent they are on the correct identification of the creatures they study. Yet Dr. L. H. Bailey, whom no one can accuse of looking on the world from a narrow museum window, has recently warned the oecologist that he may "fall into false comparisons by carelessness in identification, or by inattention to critical differentiations. It really matters very much whether a given distribution represents one specific type or two or more very closely related types; in fact, the significance of an ecological study may depend directly on allied taxonomic relationship" (Science, 29th Dec., 1917). Even Fabre, for all his magnificent disdain of the systematist, submitted the naming of his prizes to a learned entomologist of Bordeaux, and on one occasion had to confess that, since he did not at first distinguish between three species of wasp, he was unable to ascribe to each of them its respective nest.

But the experimental embryologist! He will conduct ingenious experiments for weeks or months, will promulgate revolutionary theses from their results, and then will calmly tell you that the eggs belonged to "the common starfish," or to "the *Echinus* of our coasts." So, when a worker on material from American waters learns that his results are not confirmed by colleagues at, say, Naples, he suggests that the sea water must be different; it does not occur to him that the species may be, probably is, different.

The geneticist and the systematist are both attacking the same problem, but the geneticist cultivates his patch more intensively and deals with differences even more minute than those of the systematist. One would expect him therefore to be even more precise in the identification of his material. Unfortunately too many papers leave the reader uncertain as to the exact species with which the writer was dealing. A large amount of work has recently been published on

inheritance in the fly, *Drosophila;* but, as Dr. L. O. Howard has written, "knowing that there are more than 50 species of *Drosophila* in the United States, it gives me an idea of inexactness when I see so many of these papers in which no species is mentioned. The writers seem to be entirely indifferent on this point" (Science, 25th Jan., 1918). In view of the curious differences in habit, mode of reproduction and development, physiological chemistry, and the like that obtain between species of closely similar external appearance, it should be plain that the most rigid determination of the material under experiment or observation is the first step on which the rest depends. The worker who omits this precaution is like a chemist calculating atomic weights from salts bought at a cheap drug store.

What is true of the purely biological sciences applies also to various branches of geology and anthropology, using those terms in their widest possible sense. Modern stratigraphy, with which is intimately related tectonic geology, leading on to dynamical geology and the vast sweep of cosmogony, depends more and more on minute discrimination between the successive mutations of life forms and the study of their geographical wanderings. Here the museum systematist and the field geologist must cooperate, the latter by extensive and intensive collecting of fossils, the former by accumulating material from all horizons and regions into one place for direct comparison and intimate scrutiny. If petrology must be studied first in the field and the laboratory, it is the museum that must preserve for reference a standard series of rocks and minerals, rough-hewn, polished, weathered, in hand specimens, and in thin sections, representing all localities and the varied modes of occurrence. The ethnologist who frames hypotheses of migration without a comparative study of material coming from all parts of the world and illustrating distinct branches of human activity is bound to fall into error; it is only in museums that such a study can be made. The dependence of the archeologist on museums is no less obvious, but even the historian of later days would frequently avoid mistakes if he would make himself more familiar with the concrete evidence preserved in our museums, often a surer witness than documents colored unconsciously or with intent by the prejudices of their writers. Thus, in the hands of Mr. A. W. Pollard, the technical details of certain printed books have thrown on the history of religious toleration, of the liberty of the press, and of the theater in this country, a clearer light than was afforded by existing written statements. Or, again, the history of the scattered Greek communities from 700 to 300 B. C. is wonderfully elucidated by the history of their coinage which Prof. Percy Gardner has just published. And, as the Times puts it, "without the stately array of volumes which form the British Museum Catalogue of Coins," the latter history "could not be attempted."

It would be possible to amplify the preceding sketch of the relations which museum work bears to the various branches of knowledge, one might even extend the principles to the arts and crafts; but enough has perhaps been said to explain the conclusions which follow and to justify the dogmatic form in which they are cast.

The first business of the museum is to afford a safe and permanent home for collections of material objects. These may be acquired through others, or the museum may with advantage send out its own collectors. That is a question of administration; the essential duty of the museum official is the preservation of the specimens intrusted to him.

The next business is to see that every specimen is furnished with an indication of its original locality, mode of occurrence, and any historical facts concerning it. Many ways of doing this are familiar to curators.

Then the specimens must be arranged in such a manner as to be readily accessible for reference by accredited students. To accomplish this is required, first, a logical scheme of classification. This scheme must be practicable for the curator, who is inevitably governed by the mode of preservation of his specimens (e. g., in spirit, or skins, or fossils). On the other hand, it must be in relation with the scheme adopted by the majority of students—what they would admit as a "scientific" classification. The curator therefore must be familiar with scientific studies, and he must have such knowledge as will enable him to perform the necessary preliminaries of identifying and sorting. Since no museum in the world has a staff large enough to permit of its officials having the detailed knowledge required, every museum in greater or less degree is obliged to call in the aid of specialists. The modes of obtaining this outside help are various, but there is no need here to reveal the secrets of diplomacy. However they be persuaded, such namers and sorters are for the nonce museum workers. The official curator has to gather up and apply the results of their labours.

Next, for the museum to be of its full value to the scientific public, especially to workers in other countries, it is necessary to publish catalogues. These need not always rival the monographic volumes issued by the British Museum, but they must follow the scientific classification and must be something more than mere lists. Their compilation requires critical judgment and thorough knowledge, so that here, also, the services of outside helpers are needed.

The constant acquisition of novelties that will not fit into existing classifications, and the discovery of new facts concerning species or objects long known, necessitate a perpetual revision of the systematic arrangement. Hence the museum worker can be no mere recorder of the obvious or converter of other men's labours, but is himself

forced to extend the bounds of science. Applying his continuous experience to a large store of specimens from far and near, the museum systematist may often have a broader view than one whose studies (more attractive, more profound if you will) have been limited to a single country or to a few isolated species. But he will rightly desire to base his conclusions on something beyond his museum experience, and nowadays the better type of museum worker generally does so. Again, to quote Doctor Bailey:

> We do not realize that there is now appearing the modern systematist, who is not an herbarium hack, but a good field man, an evolutionist and plant geographer, one highly skilled in identification, and reinforced by much collateral training of a highly specialized character.

Let this, however, be quite clear. It is not the business of the museum man, as such, to conduct experimental research, to make field surveys, or to apply his knowledge to industrial processes. It is his business to supply the labourers in all these other fields with the particular kind of knowledge that the museum can best or can alone furnish. He can, as our Mauritian story showed, identify specimens for them, throw light on their origin, give information as to their natural environment, and thus suggest further research or practical applications of the knowledge already to hand. Some may say: "If this is all, why should not a library serve our purpose?" For one reason, as appears from the same story, because the facts to be gleaned from museum collections are to be found in no library. In any case the identification and comparison of specimens are far more easy, rapid, and certain by means of collections. The opinions of the museum expert are based on knowledge drawn from the actual specimens in the museum. Mere book-learning is of no avail. Moreover, no expert carries all his knowledge in his head. He is an expert because he is, as it were, a part of his collections and understands how to use them for his researches. Those who send enquiries to our museums often seem to think that an answer can be despatched by return of post. More often is it the case that a single question demands hours, days, or weeks of study. The search for evidence, the piecing together of scattered threads, and the formulation of exact results make up a lengthy process for which continuity and the concentration of attention are required.

But we want the public of scientific and of practical men to realize that we are wishful to help them, not indeed by doing their work for them, but by opening to them the resources of our museums. It is a great pity that workers in general do not make more use of the museums. How often, after reading some elaborate memoir, do we not exclaim: "If only the silly fellow had taken the trouble to come to us, what a lot we could have shown him!" The pity of it is that science is the loser, and the world at large the sufferer. A

few striking instances are fresh in my personal experience, but I refrain from closer allusion. Why should this be? Is it laziness, or is it not rather part of that ignorance which it is an object of this article to dispel? Probably the latter, for a well-known British zoologist was recently found to believe that the specimens exhibited in the public gallery represented the whole collection of fishes in the Natural History Museum. He may have been an extreme case, but he was not an isolated one. Few, indeed, appreciate the riches of the museum, or the facilities placed by its officers at the disposal of all single-minded seekers after knowledge.

It is also not realized how glad we should all be to accept and to retain for future generations of scientific workers the material used by the researchers of to-day. It would certainly be of great service to retain samples of the plants and animals used in important breeding experiments; by this I do not mean mounted exhibits, such as we have at the Natural History Museum, but ordinary adult specimens of the actual material, prepared for storage. If that were done there need never be any uncertainty as to the species with which anyone had worked, and, though names might change, the standard specimen would remain a perpetual witness. Microscope slides constitute another form of evidence which might be preserved in museums with the greatest ease. Slides that remain in private ownership are generally destroyed.

If the true nature of museum work is not understood, even by men of science; if the advantages to be gained from a greater use of museums are not realized; if there is distrust rather than cooperation between those who are working for the same end by diverse methods—then it may be that the fault is in part our own. Perhaps we withdraw too ostensibly from the *profanum vulgus*, and display too little interest in men and matters outside the walls of our den. In our own interests, as well as in those of our country, this state of things must not continue. We must no longer pretend that the more or less intellectual gratification of the man in the street is our chief aim. Let us dare to be frank with the people, neither deceiving them as to our objects, nor leaving them ignorant. The popular articles being issued by the United States National Museum, and largely intended for use by the press, are an example of judicious and dignified advertisement most worthy of our imitation. It sounds a truism to say that the greatest enemy of knowledge is ignorance, but for all that the remark will bear some pondering over. If we can not justify and explain our particular bits of work to the men of ordinary education, we may find possibly that we can not justify them to ourselves. That, at any rate, would be a gain. I believe that the most esoteric branches of museum work can be justified, to ourselves, to our scientific colleagues, and to the public; and that it is our bounden duty to do so without delay.


LEONHARTVS FVCHSIVS
ÆTATIS SVÆ ANNO XLI

LEONHARD FUCHS, PHYSICIAN AND BOTANIST, 1501–1566.[1]

By Felix Neumann.

(With 7 plates.)

I.

One of the most wonderful chapters in the history of mankind and in the development of the human mind is that period of the late Middle Ages, particularly the fifteenth century, which we call the Renaissance, or the time of the humanists. Literary in its aspect, it gave birth to the revival of learning and paved the way for the modern spirit of Europe. The study of classical antiquity as disclosed in literature, art, philosophy, and science of ancient Greece and Rome became the object of all scientists of that epoch and infused new life into the spiritual stagnation of former centuries.[2] The invention of printing in the middle of the fifteenth century revolutionized and facilitated the dissemination of knowledge; the discovery of a new continent near the close of that century enlarged the geographical and spiritual horizon and opened unlimited perspectives to the human mind. This was the foundation on which learning in the sixteenth century was built, and with this begins our modern history.

Humanism originated in Italy and spread slowly over Europe. In Germany it took root about the end of the fifteenth century, and it reached its zenith in the first two decades of the sixteenth century so that Ulrich von Hutten enthusiastically exclaimed:

> The mind is awakening, arts and science are flourishing. Oh, century, what pleasure to live in thee![3]

The study of classical antiquity naturally manifested itself in the prevalence of philological studies, and stamped all investigations in the various branches of science of that epoch. No other branches

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[1] Read before the Society of Medical History of Chicago, Jan. 15, 1917.

[2] Voigt, Georg. Die Wiederbelebung des klassischen Altertums oder das erste Jahrhundert des Humanismus. 2 Bde. 3. Aufl., besorgt von M. Lehnerdt. Berlin, G. Reimer, 1893.

[3] "seculum! O literae! Juvat vivere . . . Vigent studia, florent ingenia."—Ulrichs von Hutten Schriften, hrsg. von Eduard Böcking. Epistola ad Bilibaldum Pirckheymer, 25 Oct. 1518. Bd. I, p. 217. Leipzig, B. G. Teubner, 1859.

showed this influence of humanism more than medicine and natural science, and it is no exaggeration when the philosopher Windelband[1] says in his history of philosophy:

Natural science is the daughter of humanism.

The history of medicine in the thirteenth and first part of the fourteenth century covers that period which has been called the Arabic era; a period which gave a new impetus to the scientific evolution in medicine and enriched medical science in many fields. But while the Arabic influence is not to be underrated, it became evident upon the revival of learning and under the growing influence of classical studies, especially of Greek, that the Arabic medical writers, including Avicenna, had never had access to the originals of the great medical writers of antiquity and therefore had either misinterpreted or misunderstood their doctrines. It was felt necessary to go back to the original source of information, to study the great writers in their original language, to examine critically their writings, to compare the different texts, and to annotate them for better understanding. This was the origin of that tendency in medicine during the latter part of the fifteenth and the first part of the sixteenth century which stimulated the scientific endeavors of many medical writers, who formed what Haeser[2] so appropriately terms "The philological medical school."

II.

The most prominent of these writers, equally distinguished for his learning both in philology and in medicine, and also as one of the founders of scientific botany, is Leonhard Fuchs, whose name is commemorated by the genus Fuchsia named in his honor. While in the histories of botany Fuchs is treated with that thoroughness which he deserves, the historiographers of medicine have paid less attention to him with the exception of Kurt Sprengel.[3] Haeser, in the short chapter devoted to the philological medical school, mentions him among the other writers who belong to this circle. The character of Pagel-Sudhoff's introduction to the history of medicine[4] precludes a detailed sketch of his life and work.

Leonhard Fuchs, born in 1501, at Wemding, Bavaria, was the son of Johann Fuchs, a councilor of the same town, and of Anna Denton, whose father was also a councilor. Since his father died when he was

[1] Windelband, W. Geschichte der neueren Philosophie. 5 Aufl. 2 Bde. Leipzig. Breitkopf & Härtel, 1911.

[2] Haeser, Heinrich. Lehrbuch der Geschichte der Medizin. 3. Bearbeitung. 3 Bde. Jena, H. Dufft, 1875-82.

[3] Sprengel, Kurt P. J. Versuch einer pragmatischen Geschichte der Arzneikunde. 3 Aufl. 5 Bde. Halle, J. J. Gebauer, 1821-28.

[4] Pagel, J. L. Einführung in die Geschichte der Medizin. 2. Aufl. Durchgesehen von Karl Sudhoff. Berlin, S. Karger, 1915.

only 5 years of age, the credit for his education belongs to his mother. He first attended school in the town of his birth, and must have manifested exceptional ability and zeal for learning even at that early age, for he was only 10 years old when his mother, who evidently was in good circumstances, sent him to Heilbronn, in Würtemberg, to a school which had won a great reputation under a certain Conrad as head master, who instructed in Latin and read with his pupils the comedies of Terence and the odes of Horace. Here he made such rapid progress within a year that it was thought advisable to send him to the St. Maria School at Erfurt in Thuringia. There he remained a year and a half and distinguished himself to such a degree that he was able to enter the University at Erfurt when in his thirteenth year. He pursued his studies with the same eagerness and success as before, and the baccalaureate degree was conferred upon him. He was also given an appointment as instructor in the same institution. He returned to his home town for a short interval and, although very young, conducted a school with great success. But his ambition and zeal for learning was not satisfied, and in 1510 he betook himself to the University at Ingolstadt, Bavaria, where he studied philology and philosophy. The University of Ingolstadt since its foundation in 1472 had taken a prominent part in the dissemination of humanism[1] and had counted among its teachers scholars of the highest scientific reputation, among them none more famous than Johann Reuchlin, perhaps the greatest of the humanists, the resuscitator of Hebrew and Greek learning, and who is rightly called "the Father of the Reformation." This great man was one of the chief teachers of Leonhard Fuchs, with whom he studied Greek, Hebrew, Latin, and philosophy. Another teacher of high standing was Jacobus Ceporinus, who was also his instructor in these three languages. In 1521, when 20 years of age, Fuchs finished his studies, after having received his master's degree.

During this period he acquainted himself with the writings of Martin Luther and accepted his doctrines, a fact which had great influence on his life. Indeed, it is not impossible that the acceptance of the new creed led him to the study of medicine. His critical mind was awakened and sharpened; he was essentially a man of facts, although still very young. For three years he studied medicine at the University of Ingolstadt, but he did not neglect his classical studies, which enabled him to read fluently and to understand thoroughly the noted Greek writers and made him one of the best Latin writers of the sixteenth century. On March 1, 1524, he acquired the degree of doctor of medicine, then moved to Munich where he practiced his profession successfully. His residence in Munich, where he married

[1] Bauch, Gustav. Die Anfänge des Humanismus in Ingolstadt, München, R. Oldenbourg, 1901.

Anna Friedberger of the same place, covered little more than two years, for in May, 1526, he returned to Ingolstadt to become a lecturer of medicine at the university, and also to practice his profession. He must already have won some distinction in this direction, for otherwise Margrave George of Ansbach would not have appointed him his court physician. He entered upon his new duties in May, 1528, and soon gained the confidence and friendship of the margrave, who also had accepted Luther's doctrines. He became known as a successful physician, especially through his treatment of the English sweating disease, which in 1529 spread over a large part of Europe. I can not find any publication of his, either in Latin or in German, which deals with this subject, but I find in the Catalogue of Printed Books in the British Museum the following entry:

> A most worthy practise of * * * L. Fuchsius * * * moste necessary in this nedeful tyme of our visitation * * * both for the sicke and for them that would avoyde the daunger of the contagion. Rouland Hall for M. [ichael] Lobley. London, n. d.

This copy is the only one in existence, so far as I am able to trace; it evidently refers to Fuch's treatment and cure of the English sweating sickness. Added to the entry, in brackets, is the date 1575, with a query; but this date is without question a mistake. The sweating sickness[4] visited England first in 1486, again in 1507, 1518, and 1529 (in which latter year it spread over a large part of Europe), and the last time in 1551. The book must have been printed at an earlier date than 1575, for we know that Michael Lobley flourished in London as a bookseller between 1531 and 1567, and that the printer Rouland Hall died in 1563.[5]

In connection with this book, I wish to mention another work, the authorship of which is attributed to Fuchs, and which, while dealing with a different subject, may be characterized as an undertaking of similar character. Albrecht von Haller quotes in his Bibliotheca medicinæ practicæ (Vol. I, 1776), among other writings by Fuchs: Tabula oculorum morbus comprehendens, Tubingæ, 1538, folio, which entry Wilhelm Gottfried Ploucquet, 20 years later, copied in his Initia bibliothecæ medico-practicæ et chirurgicæ, vol. vi. These are the only two bibliographers who mention this work; in the history of ophthalmology it was not known. In 1890 Dr. Edward Pergens, of Brussels, a well-known oculist, and greatly interested in the history of his specialty as well as in the history of medicine,

[4] Hecker, J. F. C. Der englische Schweiss, ein ärztlicher Beitrag zur Geschichte des 15 und 16. Jahrhunderts. Berlin, T. C. F. Enslin, 1834.

[5] As the service of the British Museum is limited during the present war, I will communicate with the librarian after the war and will ask for a photostat copy, which may enable me to give some more information as to whether the book was really written by Fuchs or whether it was the undertaking of an enterprising bookseller who took advantage of an illustrious name to stimulate the sale.

published in volume [illegible] of the Centralblatt für praktische Augenheilkunde[1] an exact reprint of what seems to be a German translation of the Latin edition of 1538. The book is entitled: Alle Kranckheyt/der Augen durch den hochge/lerten Doctor Leonhard fuchsen zu Onoltz/bach zusammen gezogen allen augen/artzten hochnöttig zu/wissen. Getruckt zu Strassburg durch Heinrich Vogtherren Anno/MDXXXIX.

The reprint is preceded by a brief historical introduction, in which Doctor Pergens quotes the Latin edition, according to Ploucquet (that Haller had mentioned it first had escaped him), and then presents a history and description of the German copy. Doctor Pergens had found the work in the Bibliothèque Royale at Brussels. The book contains an illustration on the reverse of the title-page, reproducing a figure of the eye with a part of the chiasm. (Plate 2.) Whether this illustration is an original one, Doctor Pergens does not decide; three years later this illustration was reproduced by Jakob Ryff in his Kleinere Chirurgie, Strassburg, 1542. The copy found in Brussels by Doctor Pergens is not the only one. Prof. Julius Hirschberg, of Berlin, found another copy in the Koenigliche Bibliothek in Berlin, and I myself was so fortunate as to find still another copy enumerated in catalogue No. 319 of K. F. Köhler's Antiquarium, Leipzig, 1879, No. 28. Perhaps this copy is identical with one of the copies in the libraries mentioned.

Doubt of the authorship and criticism of the scientific value of the German edition are not expressed by Doctor Pergens. The question of the authorship of the German edition and the question of the existence of the Latin edition is taken up by Professor Hirschberg[2] in his Geschichte der Augenheilkunde. Stimulated by Doctor Pergens' article and by the reprint of the German edition, he made a thorough search for the Latin edition in all the German libraries, but without success. Not discouraged, Hirschberg carefully examined the chief medical work by Leonhard Fuchs, Institutiones medicinae, and his labor was not in vain. He found in Liber III, sectio I, capitulum xii: "Vitiorum oculi succincta explicatio," the original of the so-called German edition, "but," he adds, "without the ridiculous mistakes and without the ill-fitting therapeutic interpolations, and, of course, without the supplement which consists of prescriptions." Hirschberg is completely convinced that the German edition was not written by Fuchs. From internal evidence he takes it for granted that Jörg Vogtherren, and Conrad and Bartholomaeus Vogtherren, relatives of the printer Heinrich Vogtherren, are responsible for the book,

[1] Leonhard Fuchs' alle Kranckheyt der augen (1539), neu herausgegeben von Dr. Ed. Pergens (Brüssel), p. 197–203; 231–238.

[2] Hirschberg, Julius. Geschichte der Augenheilkunde. 2. Aufl. II. Bd. S. 316–319, Leipzig, W. Engelmann. 1908.

having used the name of Leonhard Fuchs without authority. This theory is very plausible, as the same printer issued anonymously in 1538, and again in 1539, a book, which deals also with the eye. The title is as follows: Eyn Newes hochnutzlichs Buechlin/und Anothomi eynes auffgethonen augs auch seiner/erklaerung bewerten purgation Pflaster Colliri/en Sälblin puluern vnnd wassern wie/mans machen vnd brauchen sol. Getruckt zur Strassburg durch Heinrichen/Vogtherren. Anno MDXXXIX. (Plate 3.)

The Surgeon General's library has a copy each of the editions of 1538 and 1539, but unfortunately the former lacks the title-page. The edition of 1539 has on the title-page, below the title, an illustration: "Anatomia oculi," which does not differ materially from that reprinted in the so-called German edition by Leonhard Fuchs.

I now resume the narrative of Fuchs' life. The time spent by him at Ansbach, which lasted five years, or until 1533, was not entirely consumed by his duties as court physician and by his general practice. A born student, by temperament and habit a scholar, he here laid the foundation of his career as medical writer and man of science. As a complete bibliography of Fuchs has not yet been compiled, a want already expressed by Ernst H. F. Meyer,[1] the historian of botany, it is not an easy matter to harmonize the many contradictory statements in regard to the dates and the number of his numerous writings. Some authors attribute to him, as written in Ansbach, three books, some four, and others even more. As I shall give a description of his writings later on, it is here sufficient to state that they gained for him the reputation of a very learned writer, who possessed original ideas, and who had the courage of his convictions. This caused the famous jurist and chancellor of the University of Ingolstadt, Leonhard von Eck, to request Fuchs in 1533 to rejoin the teaching staff of that university by tendering an assistant professorship of medicine, which Fuchs accepted. I have already stated that, while a student in Ingolstadt, Fuchs had familiarized himself with the writings of Luther and had become a strict adherent of his doctrines. In Ansbach, where the margrave and the court were also followers of the new creed, Fuchs found mutual understanding and was accustomed to express his religious convictions with candor and frankness. In Ingolstadt, however, conditions were different, and especially in the university; here Fuchs met very strong opposition, particularly as he did not suppress his opinions. Under these circumstances Fuchs' position at the university became untenable, and in August of the same year he left Ingolstadt to return to Ansbach at the invitation of the margrave. But as Ansbach became infested with the plague, he accompanied the margrave to

[1] Meyer, Ernst H. F. Geschichte der Botanik. 4 Bde. Koenigsberg. Gebrüder Borntrāger, 1854–57.

Culmbach, where the court resided for some time, returning in 1534 to Ansbach. In the same year Fuchs published his Paradoxorum medicinæ libri tres and dedicated it to Ulrich, Duke of Wurttemberg, which was evidently the reason why the duke, who was just beginning to reform and to rejuvenate the University of Tübingen, appointed Fuchs as professor of medicine in 1535 to replace Prof. Rudolf Unger, who was more than 70 years of age and no longer able to adapt himself to the reforms contemplated by the duke. On August 14, 1535, Fuchs entered upon his duties in Tübingen, where he lived and labored until his death, 31 years later. In his dedication to the duke, Fuchs states that the medical school of Tübingen, which had once given to the medical profession such excellent scholars, had greatly deteriorated and had lost its prestige. To modernize this school and to make it regain its once illustrious name as a seat of learning was Fuchs' chief aim, and in this he had the full support of the duke. In an order,[1] dated November 3, 1536, concerning the reform of the university, Duke Ulrich stipulated that two ordinary professors of medicine should lecture daily and read with the students those books necessary for the understanding of their science, especially Hippocrates and Galen, in Greek. The two ordinary professors were Leonhard Fuchs and Michael Rucker.[2] The appointment of the latter was unfortunate. He still belonged to the old school of medicine, and Duke Christopher, Ulrich's successor, said of him that he had peculiar opinions and bad habits. Fuchs was not only the leading spirit in the medical faculty but unquestionably was the most important teacher in the university. Twice he was elected rector, from 1536 to 1537 and from 1540 to 1541, and the statutes of the medical faculty, issued in 1539, were written by him. These statutes are important to the history of the study of medicine at German universities in the sixteenth century and show that Fuchs was inspired with the modern spirit of the time—a true humanist. The keynote of the statutes is his opposition to Arabism in medicine. "Those who study medicine from the Arabic writers," he says, "will draw water from turbid rivers."[3] The Greek writers, as Hippocrates, Galen, and Dioscorides, should be studied in their own lan-

[1] Urkunden zur Geschichte der Universität Tübingen aus den Jahren 1476–1550, Tübingen, H. Laupp'sche Buchhandlung, 1877, S. 189: "Zum fünften zwen Medici ordentlich zum wenigsten und teglichen lesen und lernen, die Bücher zu verstand der kunst, und dem gebruch dienstlich, fürnemlich Hippocratis und Galeni, mit behilff der griechischen sprach, die dann dise in iren schrifften gebraucht hatten."

[2] "Michael Rucker von Wiesensteig imm. 1521, Mag. 1526, Med. D. 1530. Er war kein Freund der neuen Lehre. Noch 1556 sagt eine Instruction H. Christophs von ihm, er sei nit allein ein Papist, sondern habe noch mehr besondere opiniones und Untugenden. Stirbt 1561."—Urkunden z. Geschichte d. Universität Tübingen, S. 166.

[3] "Et quum notum sit, [illegible] Arabes omnia ferme sua e Graecis transcripsisse, [illegible] ad doctrinam studii hujus adhibeantur, quod consultius sit artis praecepta a fontibus, quam turbidis rivulis haurire."—Urkunden z. Geschichte d. Universität Tübingen, S. 311.

guage, and he enumerates the works of Hippocrates and Galen which should be read and explained during the lectures. Then comes an innovation in the study plan of universities: During the summer months the students of medicine should often go to the country and to the mountains, and with intelligence collect and study the plants;[1] this study should become a part of the curriculum in medical schools. As Fuchs, himself, paid special attention to the study of anatomy, he took the reform of this important branch of medicine very much to heart. While the old statutes of the medical faculty, issued in 1497, ordered a dissection only every three or four years, he dissected twice a year whenever possible. He also discontinued the use of Mundinus's anatomy in his lectures on anatomy, and himself subsequently wrote the handbook Libri quatuor de fabrica corporis humani, which was used a great deal in German universities during the sixteenth century. While he still had great admiration for Galen as an anatomist, Fuchs also extolled the great work of Vesalius, for whom he entertained the friendliest feelings, calling him "Summus noster amicus," a friendship that Vesalius reciprocated. The two had met when Vesalius came with the imperial troops to Tübingen. An interesting account of their first meeting is given by Crusius in his Annals.[2]

Vesalius visited incognito the anatomical lectures given by Fuchs. One day Fuchs made some derogatory remarks concerning Vesalius' anatomy. At the close of the lecture, Vesalius approached Fuchs: "Why," he courteously inquired, "do you find fault with me? In what way did I do you any harm?" "Are you Vesalius?" asked Fuchs. "You see Vesalius himself," replied the latter. Then followed the expression of mutual pleasure, a friendly meeting and an invitation to Vesalius to be Fuchs' guest. That his reputation as anatomist, physician, and medical teacher was recognized, not only in Germany but in foreign countries as well, is evident from the fact that Duke Cosmo de Medici of Tuscany asked Fuchs to become Vesalius' successor at the University of Pisa. Hitherto Germany had called to its universities scientists from Italy, but this offer to Fuchs was the first instance that a German scholar was called

[1] "Aestatis denique tempore cum medicinae studiosis rura montesque saepius petat ac plantarum vultum diligenter observet illasque vivas [illegible] imagines demonstret, neque ut hactenus consuevere [illegible], simplicium medicinarum explanatio illis hominibus rudibus et stultis mulierculis committatur. Haec itaque deinceps ratio posthac in scholis medicis observetur." Urkunden z. Geschichte d. Universität Tübingen, S. 512.

[2] Crusius, Martinus. Annales Suevici, 3 pts. Francofurti, 1595-96.—Pt. III, 729: "[illegible] Hispanorum [illegible] quando in praesidiis hujus Ducatus erant, lectiones quoque frequentarunt ejus et curationes ejusdem [illegible]. Quodam die carpsit, nescio quid, in Anatomicis Vesalii auscultante peregrino viro. Lectione finita, is ad Fuchsium accedens cur me, excellens inquit, reprehendisti? Qua in re te laesi? —Esne tu Vesalius, inquit Fuchsius. Vides ipsum Vesalium, refert hic.—Tum inter eos gratulatio, amica collatio et ad convivium invitatio."

to fill a chair in an Italian university. Much earlier, in 1537, Duke Albrecht of Prussia had endeavored to persuade Fuchs to become court physician to his brother-in-law, King Christian III of Denmark, and also professor of the medical school of Copenhagen.[1] These two offers, which were distinct honors for Fuchs, Haller evidently had in mind when he said in his Bibliotheca medicinae practicae that Fuchs was the first German physician whose fame reached beyond the borders of his own country. ("Primus inter Germanos ad magnam celebritatem apud exteros pervenit.")

Another medical subject in which Fuchs took special interest next to anatomy was his lectures on the practice of medicine. In these, as in his writings, his chief aim was to exclude as much as possible the Arabic writers from the medical curriculum, but instead to read and explain the Greek medical writers. This leads us to Fuchs' activity as a medical writer, which is very comprehensive. His writings on this subject may be divided into three sections: (1) Translations of and commentaries on Greek writers; (2) his own contributions; and (3) his polemic writings.

There are nine translations and commentaries, of which five deal with Galen, three with Hippocrates, and one entitled Nicolai Myrepsi Alexandrini medicamentorum * * * Hactenus in Germania non visum * * * e Graeco in Latinam recens conversum luculentissimisque annotationibus illustratum, Basilaae, 1549 (Plate 4); and several times reprinted. This translation of a Greek manuscript has an interesting literary history. The author of this collection of prescriptions is really Nicodemus Myrepsus[2] Alexandrinus,[3] who flourished from the middle to the end of the thirteenth century. Fuchs supposed him to be identical with Nicolaus Prepositi,[4] whom he confounded with Nicolaus Salernitanus, who lived at Salerno at the beginning of the twelfth century, a mistake committed also by other medical writers and bibliographers. We are indebted to Ernest Wickersheimer, librarian of the Académie de médecine in Paris, for correcting this bibliographical blunder. In an instructive article[5] published in 1911 (Archiv für Geschichte der Medizin, Bd. V, 302–310) he was able to prove that Nicolaus Salernitanus, wrongly called Prepositus and Nicolaus Prepositi are two distinct writers; the latter was a student at the University of Paris in 1472, and evidently flourished until the early years of the sixteenth century.

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[1] Voigt, Joh. Briefwechsel der berühmtesten Gelehrten des Zeitalters der Reformation mit Herzog Albrecht von Preussen. Koenigsberg, Gebrüder Borntraeger, 1841.

[2] Μυρεψός, apothecary.

[3] After the city of his birth, Alexandria.

[4] "Quod certo comperiet, qui fragmentum hoc quod passim sub Nicolai Praepositi nomine circumfertur". . . . Nicolai Myrepsi Alexandrini Medicamentorum opus . . . , a Leonhardo Fuchsio . . . e graeco in latinum recens conversum. . . . Basileae, 1549. Praefatio, A², recto.

[5] Nicolaus Prepositi, ein französischer Arzt ums Jahr 1500; von Er. Wickersheimer (Paris).

Fuchs' original writings, not including the various editions and reprints, are about 20 in number, most of them dealing with the method and practice of medicine, and with materia medica. The three most important are: (1) Libri quatuor de fabrica corporis humani, Tubingae, 1551, which I have already mentioned. Next to Vesalius' great work this was considered the best handbook of anatomy in the sixteenth century, and was much used and frequently consulted, as it best represented the various anatomical doctrines of the time. (2) Paradoxorum medicinae libri tres, Basilae, 1535. The first book deals only with pharmacology; the second treats questions of general and special pathology and therapy, and the third contains anatomical and physiological criticisms. This work and (3) Institutionum medicinae libri quinque, form Fuchs' chief weapons against Arabism in medicine. Only a writer of such learning and reputation [redacted] Fuchs could risk saying that Avicenna, who, though he copied the Greek writers, did not understand them, should *not* be considered as the greatest physician.

Two books are to be mentioned which have as their subject materia medica and therapy: Annotationes de simplicibus a medicis hactenus perperam intellectis et aestimatis, Argentorati, 1532, and De componendorum medicamentorum ratione, Basileae, 1540. Schelenz,[1] in his Geschichte der Pharmazie, says that the Annotationes were still in use in Cologne in apothecary shops in 1627. The De componendorum medicamentorum ratione was used as a handbook in the pharmaceutical lectures of many universities as well as in pharmaceutical practice.

Fuchs' polemic writings are numerous; some are controversies of a scientific character, others are caused by piratical undertakings of publishers. The most important one, famous in the history of medicine, is: Apologiae tres, adversus Guilelmum Puteanum, Sebastianum Montuum et Triverum Brachelium, Basileae, 1520. Its inspiration was Peter Brissot's famous work, Apologetica disceptatio de vena secanda in pleuritide, Basileae, 1529. The question of venesection (blood letting) divided the physicians of the sixteenth century into two hostile factions.[2] One, the Arabic school, asserted that venesection should be undertaken, in case of inflammations, as far as possible from the seat of the disease, and then very slowly; while the Hippocratic school, based on Brissot's doctrine of revulsion, recommended the venesection near the diseased part and then very copiously. Jeremias Drivere (Triverus Brachelius), Sebastian Montuus, and Wilhelm Puteanus defended the Arabic theory, while Fuchs sided with Brissot. Fuchs was without question the best informed and most

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[1] Schelenz, Hermann. Geschichte der Pharmazie, Berlin, J. Springer, 1904.
[2] Bauer, Jos. Geschichte der Aderlässe. München. Beck, 1870.

persistent defender of the Hippocratic school. The controversy lasted almost throughout the sixteenth century and ended with the victory of the Hippocratic school. This is what Fuchs has accomplished for medicine.

Here may be the place to speak of him as an academic teacher. Regarding the spirit in which he presented his lectures and the method which he employed, we have the testimony of his contemporary and colleague, Georg Hizler, professor of Greek in the University of Tübingen, who delivered the obituary at the memorial meeting held for Fuchs at the university. It is significant that a philologist was selected for this honor and not a member of the medical faculty. This oration was published in separate form and was reprinted in volume I of Fuchs' opera,[1] issued in Frankfurt the year of his death. (Plate 5.) Hizler[2] says:

> In the discharge of his office as academic teacher, what diligence, perseverance, and devotion! Here his enviable reputation was based on two vital considerations, to wit, sound method, and pure, perspicuous speech. In the discussion of medical authors he took the most useful and expeditious road; he never mixed in anything that was not to the point; he diligently explained the words in their true sense; he did not spend more time than the topic in question required; he did not, however, omit anything that could facilitate the explanation. Then he gave his instruction in such a clear and simple way that all could follow him with ease. Add to this the elegance of his discourse and it is plain that all listened to him with pleasure. Thus his teaching of anatomy was conspicuous for ability and clearness. He showed and illustrated all the parts of the human body and the functions of the several parts; he explained the nature of all bones and cartilages; he pointed out the various muscles, veins, arteries, nerves, and the like, and demonstrated all this 'ad oculos.'

I come now to another field of Fuchs' scientific activity, in which he achieved so much and which contributed so largely to the spreading of his fame throughout Europe.

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[1] Oratio de vita et morte clarissimi viri, medici et philosophi praestantissimi, D. Leonharti Fuchsii, artis medendi in Academia Tubingensi professoris doctissimi; a doctissimo viro Georgio Hizlero, Graecarum & Latinarum literarum in eadem professore habita & scripta.

[2] "In docendi munere quanta sedulitas, fides, diligentia? Duabus autem maxime rebus in docendo necessariis, summam consequebatur laudem: tum illa artium via, quae μέθοδος a Graecis dicitur; tum sermone puro, perspicuo & aperto. Nam in explanandis medicorum scriptis, primum expeditissimam & utilissimam viam cognoscere & inire: nihil a re alienum asserere: verba accurateque, genuinum diligentissime explicare; non diutius haerere & immorari, quam res, quae ad cognoscendum exponebatur, requirere videretur: eorum, quae necessaria ad explicandum erant, nihil omittere. Deinde tam pure, tam aperte, tam simpliciter omnia tradere, ut facillime omnes assequerentur. Itaque, non tam ordine & modo, quem servabat, optimo, quam orationis elegantia animos auditorum conciliare, ita ut cum fastidio ipsum audiret nemo. Hujus rei inter multa alia, exemplum potest esse anatome: quam docuit dexteritate & perspicuitate singulari. Humani enim corporis partes, & singularum partium actiones & figuras ostendebat: omnium ossium, cartilaginumque, naturam, musculos, venas, arterias, nervos & caetera indicabat, & oculis subjiciebat."

III.

At the outset I called attention to the influence of humanism on the revival of learning and how humanism in its immediate consequences caused and created a new phase in the evolution of medicine and natural science. One event of entirely different character enlarged and enriched these two branches of science in another direction—the geographical discoveries at the end of the fifteenth century, and especially the discovery of America. Until then the contemplation of nature was entirely neglected. From the time Pliny had written his encyclopedic "Naturalis Historia" natural science had been practically at a standstill. The discovery of America opened an entirely new field for observation of objects of natural science. The study of plant life was the first field to profit by it, and under the stimulating influence of the revival of learning botany became a science.

In this movement Germany took a leading part. Three names will always be connected with the history of botany in Germany, and it is not by chance that all three were followers of humanism; Otto Brunfels, 1484–1534; Hieronymus Bock, 1498–1554; and Leonhard Fuchs. Each of these wrote his own herbal; but Fuchs was the most prominent and the most learned of these three herbalists. In Brunfels' Herbarum vivae eicones, published in three parts in 1530–1536 by Schott in Strassburg, we admire the illustrations which are drawn true to nature, though the descriptive text is of no scientific value. The first edition of Bock's work, New Kreutter Buch von underscheydt, würckung und namen der Kreutter, so in Teutschen Landen wachsen, Strassburg, 1539, was not illustrated; the second and the subsequent editions, from which the word "new" is dropped, contain about 470 illustrations. But the chief merit of Bock's book is the text, which describes only that which he actually observed; it appeals at once to the reader on account of its popular style, and yet is full of power and vivacity. The famous book by Fuchs, De historia stirpium commentarii, Basileae, 1542 (Plate 6), surpasses the two previous herbals in text as well as in illustrations. He is the first botanical writer to attempt a botanical nomenclature. The arrangement of the work is alphabetical. In his plant description he applied the following method, which was used as a pattern by succeeding botanists: (1) The name of the plant in Greek, Latin, and German; (2) the form; (3) locality; (4) time of blossoming. The illustrations are of the highest order. Heinrich Füllmaurer and Albert Meyer drew the plants, and Rudolph Speklein, all three of Strassburg, engraved the woodcuts. To show his gratitude to these three artists, Fuchs reproduced their portraits on the last leaf of the book (Plate 7), while his own portrait (Plate 1) is found on the reverse of the title-page. The work met with the greatest success, having larger

circulation than any similar scientific work of its day. There exist in all, including translations and abridgments, 35 editions. It was Fuchs' intention to continue and to reissue the work in three volumes. From 1556 he had been collecting material and had assembled 1,500 plates, but he could not find a publisher on account of the heavy expense. He petitioned several princes, amongst others Duke Albrecht of Prussia, for support, but without avail. It is uncertain what became of the manuscript; the plates unfortunately became scattered. Part of them remained in Tübingen, and part of them found their way into the Gessner collection in Zürich.[1]

There remain to be added a few facts about the later years of Fuchs' life. Three years before his death he had the misfortune to lose his wife, with whom he had lived in the happiest union. As he was obliged to support a large family, and as the care of his domestic affairs absorbed much of the time so greatly needed for his studies and lectures, he married again, this time the widow of minister Graeter of Schwäbisch-Hall. But he only had a few years more to live, for, although he had previously enjoyed good health, his continuous application to work brought on insomnia, and he died May 10, 1566. But even while confined to his room Fuchs' interest in his studies continued.

Hizler, in the panegyric style of his time, compares him to Socrates, but those of more sober judgment will hardly go so far. Fuchs' modesty, which prevented him from assuming the rank of nobility which Charles V bestowed upon him in recognition of his services to mankind as physician and scientist, would have protested against such comparison.

I myself would compare him with Nicolo Leoniceno, who was born in 1428 in Vicenza and died in 1524 in Ferrara. Both were humanists; one in Italy, the other in Germany. Each was a reformer of medicine in his country, with the same aim and purpose—the study of the Greek writers of medicine in their own language; and the liberation of medicine and natural science from the influence of the Arabic writers.

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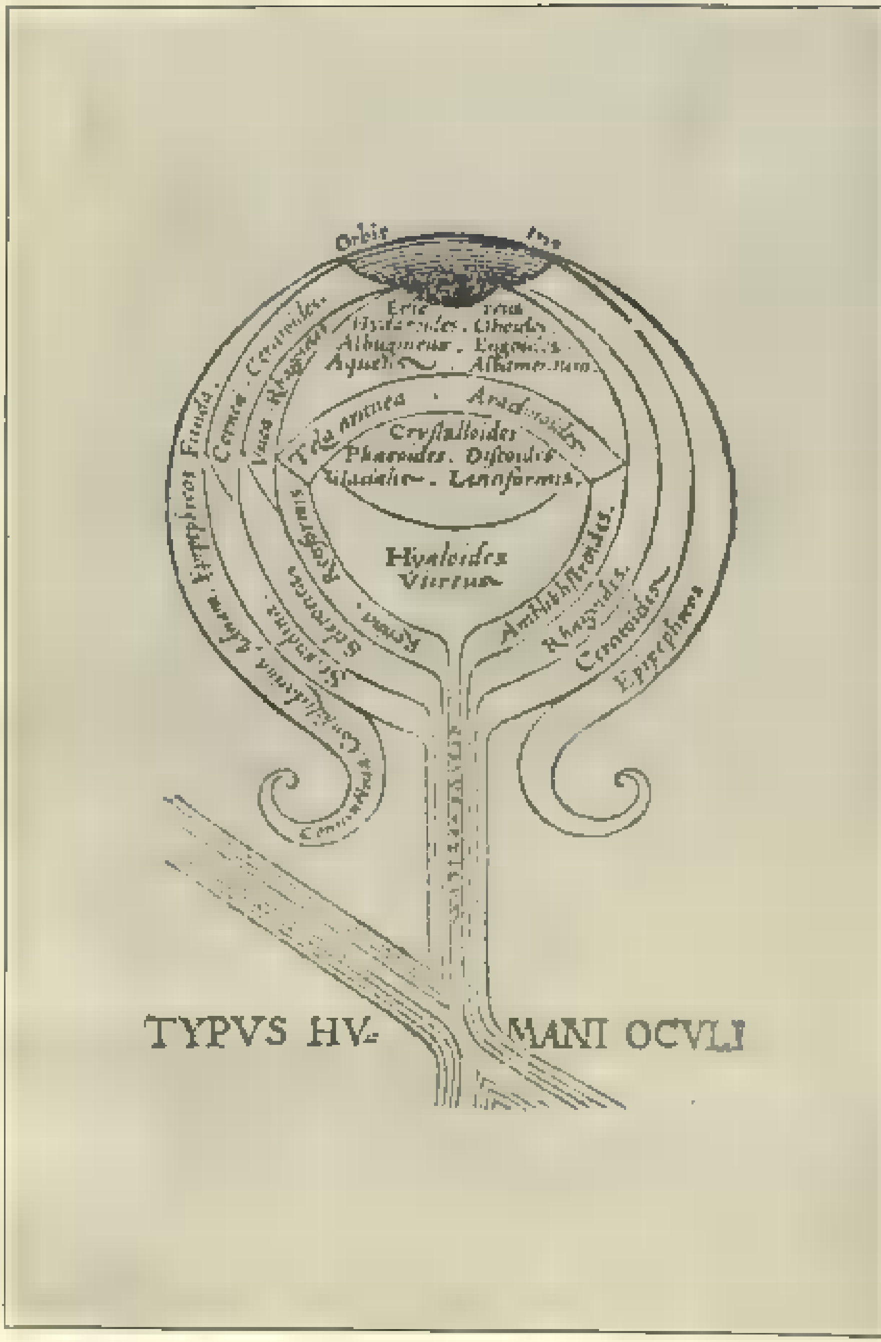
[1] Sprengel, Kurt. Geschichte der Botanik. Neu Bearbeitet. 2 Teile. Altenburg und Leipzig. F. A. Brockhaus, 1817-18.—Meyer, Ernst H. F. Geschichte der Botanik. 4 Bde. Koenigsberg, Gebrüder Borntraeger, 1854-57.—Sachs, Julius. Geschichte der Botanik vom 16. Jahrhundert bis 1860. München, R. Oldenbourg, 1875.—Roth, F. W. E. Leonhard Fuchs, ein deutscher Botaniker, 1501-1566. *In* Beihefte zum Botanischen Centralblatt, Bd. VIII, Heft 3, p. 161-191. Cassel, Gebrüder Gotthelft, 1898.—Greene, Edward Lee. Landmarks of botanical history. Part I—prior to 1562. Washington, Smithsonian Institution, 1909.


Orbis
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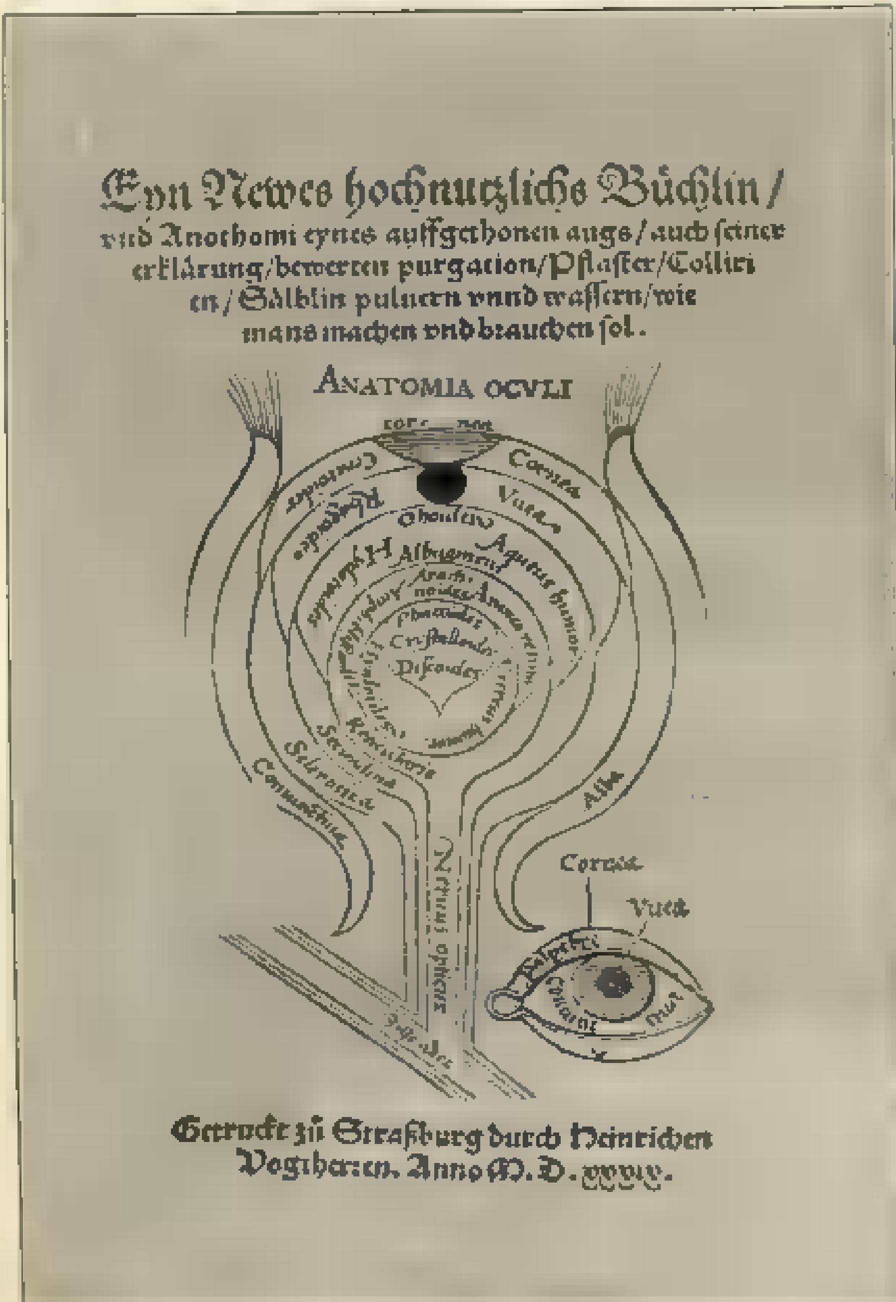

Eyn Newes hochnutzlichs Büchlin/ vnd Anothomi eynes auffgethonen augs/ auch seiner erklärung/ bewerten purgation/ Pflaster/ Collirien/ Sälblin puluern vnnd wassern/ wie mans machen vnd brauchen sol.

Getruckt zů Straßburg durch Heinrichen Vogtherren. Anno M.D.XXXIX.

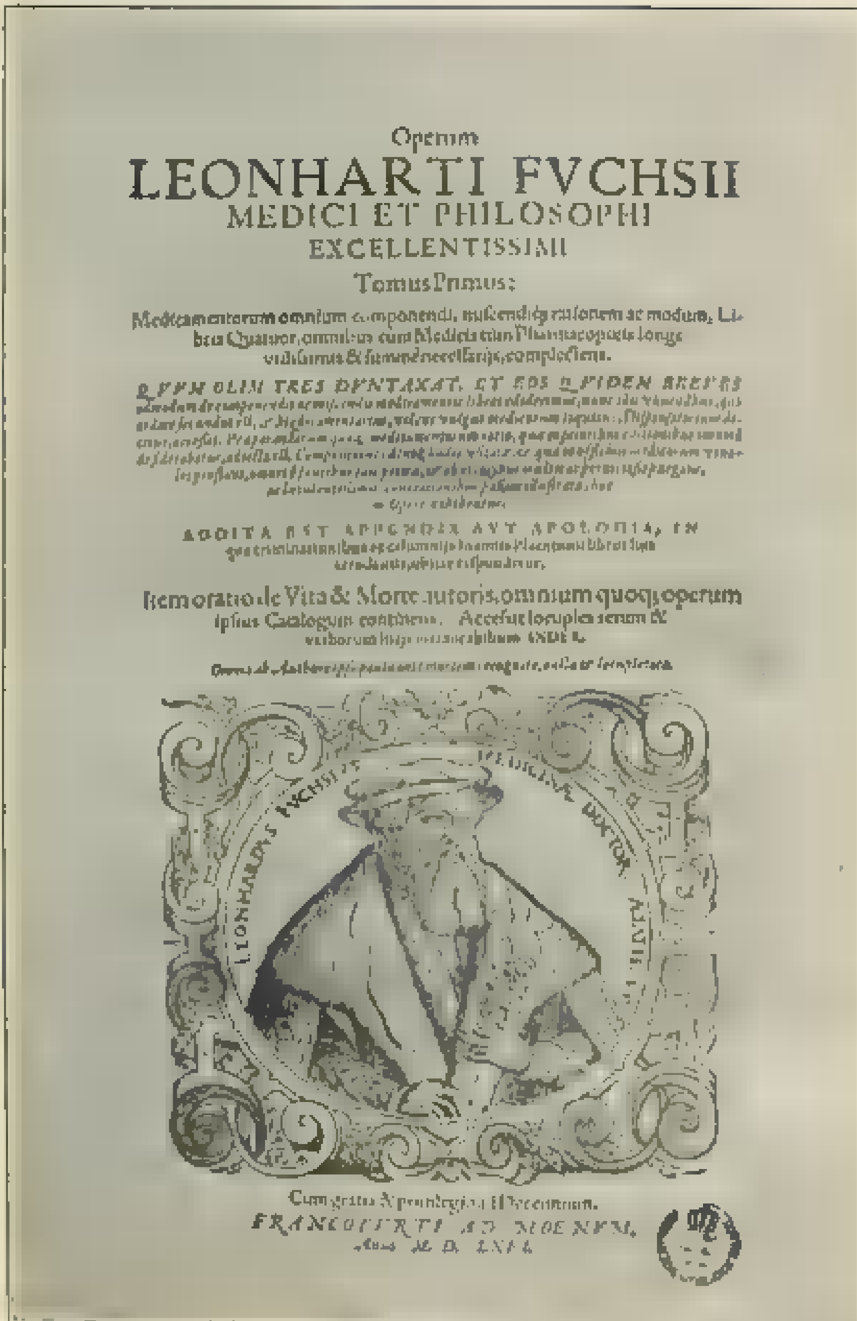
NICOLAI MYREPSI

ALEXANDRINI MEDICAMENTO-
RVM OPVS, IN SECTIONES QVADRAGINTAOCTO DIGESTVM,
hactenus in Germania non uisum, omnibus tum Medicis, tum Se-
plasiarijs mirum in modum utile, à LEONHARTO FVCHSIO
medico, & Scholæ Tubingensis professore publico, è
græco in latinum recens conuersum, lu-
culentissimisq; Annotationi-
bus illustratum.

*Accessit non solum rerum & uerborum, sed & medicamentorum
singulis morbis destinatorum locupletissi-
mus Index.*

Cum Cæs. Maiest. gratia & priuilegio ad
quinquennium.

*BASILEAE, PER IO. OPORI-
NVM, Anno 1549 Mense Martio.*



Operum
LEONHARTI FVCHSII
MEDICI ET PHILOSOPHI
EXCELLENTISSIMI
Tomus Primus:

Medicamentorum omnium componendi, miscendiq; rationem ac modum, Libros Quatuor, omnibus cum Medicis tum Pharmacopoeis longe utilissimos & summe necessarios, complectens.

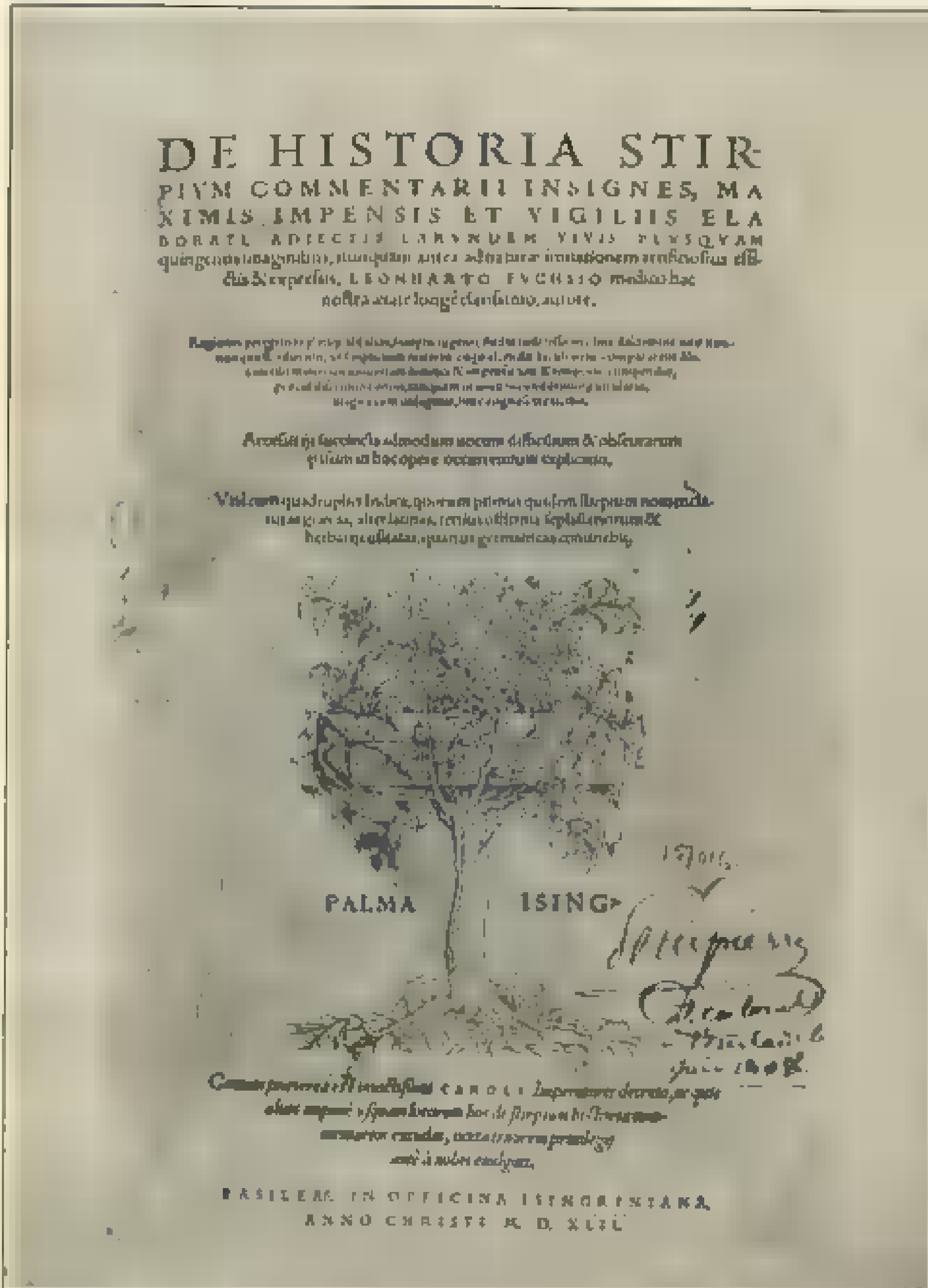
QVVM OLIM TRES DVNTAXAT, ET EOS QVIDEM BREVES [illegible]

ADDITA EST APPENDIX AVT APOLOGIA, IN qua criminationibus et calumnijs [illegible] respondetur.

Item oratio de Vita & Morte autoris, omnium quoq; operum ipsius Catalogum continens. Accessit locuples rerum & verborum [illegible] INDEX.

Cum gratia & privilegio [illegible] ad Decennium.

FRANCOFVRTI AD MOENVM,
Anno M. D. LXVI.



DE HISTORIA STIRPIVM COMMENTARII INSIGNES, MAXIMIS IMPENSIS ET VIGILIIS ELABORATI, ADIECTIS EARVNDEM VIVIS PLVSQVAM quingentis imaginibus, nunquam antea ad naturae imitationem artificiosius effictis & expressis, LEONHARTO FVCHSIO medico hac nostra aetate longè clarissimo, autore.

Accessit iis succincta admodum uocum difficilium & obscurarum passim in hoc opere occurrentium explicatio.

Vna cum quadruplici Indice, quorum primus quidem stirpium nomenclaturas graecas, alter latinas, tertius officinis seplasiariorum & herbariis usitatas, quartus germanicas continebit.

Cautum praeterea est inuictissimi CAROLI Imperatoris decreto, ne quis alius impune usquam locorum hos de stirpium historia commentarios excudat, intra tempus in priuilegio ante à nobis excusos.

BASILEAE, IN OFFICINA ISINGRINIANA, ANNO CHRISTI M. D. XLII.


PICTORES OPERIS
SCVLPTOR

Edgar A. Mearns

IN MEMORIAM—EDGAR ALEXANDER MEARNS, 1856–1916.

By Charles W. Richmond.

[With 1 plate.]

In the death of Doctor Mearns the American Ornithologists' Union has lost one of its founders and most active members, and ornithology one of its most enthusiastic disciples. Friendly and genial in disposition, with an all-consuming interest in the study of nature, he craved the society of men of similar tastes, and looked forward with keen anticipation to the rare occasions when he was permitted to attend the annual sessions of the Union. As an Army surgeon, he was subject to the vicissitudes and uncertainties of that calling, and during the greater part of his 26 years of active military service was far removed from museums and libraries, both indispensable adjuncts to the working naturalist. While this circumstance greatly interfered with his systematic studies, and prevented him from publishing any extended results of his discoveries, which he was well equipped by training and experience to perform, it undoubtedly contributed largely to his development as a field naturalist, in which field he was without an equal in this country, and enabled him to amass collections that are probably unrivaled as the efforts of a single individual. His activities of over 40 years covered a wide range, of which but little, aside from his ornithological achievements, can receive mention in the present notice.[2]

Edgar Alexander Mearns, son of Alexander and Nancy Reliance (Carswell) Mearns, was born at the home of his grandfather (Alexander Mearns), at Highland Falls, near West Point, N. Y., September 11, 1856. His grandfather, born a few miles from Aberdeen, Scotland, in 1786, came to New York in 1805, after making several

[1] Reprinted by permission from The Auk, January, 1918.

[2] The War Department was asked for a copy of Doctor Mearns's military record, but the request was refused, owing to the great amount of extra work now placed on the department.

perilous voyages at sea. He settled at Highland Falls about the year 1815, where Alexander, his son, one of seven children, was born in 1823. Doctor Mearns's father died in 1873, but his mother, who comes of New England stock, is still living.

Edgar Mearns manifested a remarkable interest in birds and animals at a very early age, and this taste was fostered by his father, who bought him a large illustrated book on the native birds. He took great pleasure in looking at the pictures—he was only 3 years old at this time—and his mother spent hours in teaching him their names and histories, and he soon developed a wonderful knowledge of the subject for one of his years. As he grew older, his father gave him a gun, and they would shoulder their arms and wander through the fields together, close companions. He was taught to set box traps in these early years, and if there was no one at hand to go with him to inspect them, he would steal out alone to see what the traps contained. As a schoolboy he was often tardy as a result of lingering in the woods in search of specimens. Every natural object interested and attracted him.

Young Mearns was educated at Donald Highland Institute, at Highland Falls, and subsequently entered the College of Physicians and Surgeons of New York, from which he graduated in 1881. At the outset of his medical course he became personally acquainted with several of the young naturalists of the time, E. P. Bicknell, A. K. Fisher, C. Hart Merriam, and others, some of whom were attending the same routine of studies. He and Doctor Fisher chanced to share the same room at a boarding house at this time, and it was here that the budding young Linnæan Society held its early meetings.

When he was about 10 years old he began to write out and preserve his observations on birds, and some of these, written in a very youthful hand, are still extant; but it was not until 1872, when a boy of 16, that his efforts had crystallized into a plan to prepare a report on the vertebrate fauna of his region, and he set to work with all the energy and enthusiasm of youth to gather material and information for this purpose. It was in the spring of this year that he seriously began a collection, and he then formed the habit of carefully labeling his specimens, noting any important items connected with each object, such as its dimensions in the flesh, the color of its eyes, and other facts of interest. This habit was faithfully followed in after years, and in birds alone it is estimated that over 60,000 measurements were recorded in his various field catalogues. He did not confine his attentions to zoology, but devoted himself to the flora as well, and unlike many young students he was ambitious to learn something of foreign species, for as early as 1875 he was in correspondence with one or

more European collectors, from whom he obtained many specimens in exchange.

His first published paper, on "The Capture of several Rare Birds near West Point, N. Y."[1] appeared in January, 1878, and it is worthy of comment that under the first species mentioned in this paper he acknowledged some information received from his "friend, Mr. Theodore Roosevelt," inasmuch as almost the last field work he ever undertook was with this same leader of men.

Three other notes followed shortly, while a paper on "The White-headed Eagles in the Hudson Highlands,"[2] presented at the meeting of the Linnæan Society of New York, on April 6, 1878, was the first communication read before that newly formed society, and was appropriately published on July 4. Toward the end of the year he had made sufficient progress with his big undertaking to look forward to a suitable medium of publication, and he wrote to Dr. J. A. Allen for advice. This letter, a copy of which was found among his manuscripts, is here reproduced, as it emphasizes the importance he attached to specific, as opposed to vague general records, and illustrates the serious and painstaking method with which he handled his subject, a method of precision that he adhered to throughout his scientific work.

137 W. 22nd St., N. Y., *Nov. 17, 1878.*

Mr. J. A. Allen,

Dear Sir: I have wanted to ask you several questions with regard to publishing a list of the Bds. of the Hudson River, and take the present opportunity to do so. Singularly enough, there is no medium of publication for such an article in this State. The "New York Academy" has recently changed very much in its character, and Mr. Geo. N. Lawrence tells me it would be impossible to get them to publish any lengthy paper on zoology, as he has much difficulty in getting them to take even brief articles of his own.

I am writing quite a bulky list of the Hudson Valley Bds., with which I am taking the greatest pains; particularly regarding dates of migration, breeding, life-habits, etc.

One of the more important points is the northern extension of the "*Carolinian Fauna*" up the Hudson.

I think the whole number of species that have been *taken* in the Hudson Valley (none others will be included), will amount to about 245.

I have been compiling the data of this list for several years. And now my object in writing to you, is to enquire whether there are any available facilities for getting the list published during the coming winter or spring. Would the "Boston Society Natural Hist.," or "Bulletin Essex Institute" do it? If you will be kind enough to advise me I shall be extremely grateful.

I have tabulated all of the specimens I have taken (1800) in Hudson region, and have formulated tables of *measurements* of all of the specimens taken. I think that these tables contain matter of sufficient interest and importance to warrant publication, in the case of the rarer species especially. As time progresses, we all know that very considerable changes take place, respecting the

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[1] Bull. Nuttall Orn. Club, III, No. 1, January, 1878, 45, 46.

[2] Forest and Stream, X, No. 111, July 4, 1878, 423; No. 113, July 18, 1878, 462, 463.

geog. distribution of the Bds. Very many ornithologists of the present day receive with incredulity many statements of the old naturalists, which may be worthy of perfect credence. Now, if *De Kay* and *Giraud*, who are about our only N. Y. State authorities had made *specific* instead of *general* statements regarding such species as *Euspiza Americana*, *Lophophanes bicolor*, *Thryothorus ludovicianus*, *Parus Carolinensis* and *Corvus ossifragus*, their observations would be of the greatest value; but many persons now doubt the accuracy of these observations. I think the tables of specimens captured and their measurements would be useful in this way if in no other. However I am quite willing to be advised in this matter.

This paper, "A List of the Birds of the Hudson Highlands, with annotations," was begun shortly in the "Bulletin of the Essex Institute,"[1] seven installments appearing between 1879 and 1881, with an "Addendum" issued in "The Auk," in 1890. As printed, it lacks the tables of measurements, these having been reduced to a simple statement of the average dimensions of each species. Doctor Allen, in reviewing the first four parts, said:

* * * His own notes, even when relating to some of our best known birds, are replete with new information attractively presented, few lists having appeared which offer so much that is really a contribution to the subject in a field where so little really new is to be looked for.

In announcing later parts, the same reviewer wrote:

The high praise accorded the earlier installments is equally merited by those now under notice, Mr. Mearns's "List of the Birds of the Hudson Highlands" ranking easily among the best of our long list of contributions to local ornithology. There [redacted] much said about the habits of various species that is entertaining or new * * *

Doctor Mearns intended this paper as the beginning of a complete catalogue of the vertebrates of the region, but his entrance into the Army in 1883 caused the abandonment of this plan, although he later (1898) published part of his data on the remaining subjects in a paper entitled "A Study of the Vertebrate Fauna of the Hudson Highlands, with Observations on the Mollusca, Crustacea, Lepidoptera, and the Flora of the Region."[2]

After completing his medical course in 1881, he married Miss Ella Wittich, of Circleville, Ohio, who shared his love of natural history, especially botany, and gave him considerable assistance with his collections. They had two children, a son, Louis di Zerega Mearns, and a daughter, Lilian Hathaway Mearns.

In 1882 Doctor Mearns took an examination for entrance into the Medical Department of the Army, but the events of that period are best told in the following extract from a letter he afterwards wrote

[1] Bull. Essex Inst., X, 1878 (1879), 166–170; XI, 1879, 43–53; XI, 1879, 154–168; XI, 1880, 189–204; XII, 1880, 11–25; XIII, 1881, 109–124; XIII, 1881, 75–85.
[2] Bull. Amer. Mus. Nat. Hist., X, 1898, 303–352.

(March 16, 1885) to his old preceptor, Robert Donald, then at Lanesboro, Minn.:

I informed you, I think, of my determination, you know it had been my wish, to enter the Army, of my coming up before the Army medical examining board and of my passing satisfactorily the examination. I did not receive my commission at once but spent the summer in settling up our business affairs and in preparing to go to New York for the winter.

I stored my collection of specimens at the American Museum of Natural History, N. Y., and on the first of October was called there as temporary curator of Ornithology, and spent the winter. While there I labeled *all* of their large collection of *European* birds, and many others from Asia and Africa, and got up catalogues of all the ornithological and oological specimens in manuscripts with printed headings for all items of desirable data concerning the specimens. The most important thing that I accomplished there was the establishment of a cabinet collection in vertebrate zoology for the use of students.

Confirmation of this last statement is found in a recent work,[1] where it is stated that "the first material for study collections was given by Dr. E. A. Mearns in 1882, consisting of skins and eggs of North American and European birds."

Doctor Mearns participated in the organization of the American Ornithologists' Union in September, 1883, and on December 3 of that year received his commission as assistant surgeon in the Army, with the rank of first lieutenant. He was offered a choice of several stations, and selected that of Fort Verde, in central Arizona, as promising an exceptional field for natural history investigations. He was accordingly assigned to this post, which he reached early in 1884. Fort Verde, abandoned as a military station in 1891, was then a desolate arid place, but to Mearns it represented a new world, peopled with strange animals and plants, all worthy of the closest study. Within sight of the fort were ancient cliff dwellings, silent reminders of a vanished race; and San Francisco Mountain, then practically unexplored, was also visible in the distance. He set to work with his customary vigor, devoting all of his leisure time to the formation of a splendid collection of the animals and plants of this section of Arizona. The ruins in the neighborhood were also examined in considerable detail, excavations were made, and thousands of relics rescued from oblivion. He wrote a delightful and extremely interesting account of these explorations under the title, "Ancient Dwellings of the Rio Verde Valley," which appeared in Popular Science Monthly for October, 1890.

During the nearly four years he was stationed at this Arizona post he was attached to various expeditions, some of them peaceful ones, others sent in pursuit of renegade Indians. In the letter to Mr. Donald, quoted above, he wrote:

We reached Fort Verde on March 25th, 1884, and, by a curious coincidence I am just in receipt of orders to leave on that day this year as surgeon in charge

[1] The Amer. Mus. Nat. Hist., its History, etc., 3d ed., 1911, 67.

of the two Cavalry regiments that are about to exchange stations between this department and Texas. I will have two acting Ass't surgeons with me, which will make my duties light, and on the 900 miles of horseback riding that I will have, there will be much leisure and opportunity for zoological and botanical work. I was given the first choice to go on this expedition, and gladly accepted for the sake of the information which I expect to acquire of the fauna and flora of the southern part of Arizona and New Mexico. The medical director is personally friendly towards me, and General Crook, who commands the Department, is particularly interested in my pursuits and has chosen me to accompany him on two long expeditions through the wildest and least known portions of Arizona. On each of these trips an entire month was spent in the saddle, and a large collection of several hundred specimens of vertebrate animals was made, which were transported, together with the rest of our plunder, upon pack mules in panniers.

The contemplated trip was duly performed, and a long account of it was recorded in one of his manuscript journals.

Doctor Mearns was popular with his brother officers, who marveled at his diligence and untiring zeal in the preparation of specimens, and many of them brought him trophies of various kinds as contributions to his collections. These cordial relations with his official associates continued throughout his career; indeed, his earnest and trustful nature and genuinely frank and straightforward character permitted no other course.

Early in 1888 he was transferred to Fort Snelling, Minn., where he remained until 1891, returning to his post again in 1903. In the winter of 1889–90, at which time he received his captaincy, a few months spent at the American Museum enabled him to describe several new mammals and birds from his Arizona collections, as well as to complete other manuscripts. During his stay at Fort Snelling he borrowed a large series of sparrow hawks from various friends and museums and investigated the geographical variation in this species, the results of which were embodied in a paper entitled "A Study of the Sparrow Hawks (subgenus *Tinnunculus*) of America, with especial reference to the continental species (*Falco sparverius* Linn.)."[1]

When the Mexican-United States International Boundary Commission was organized in 1891, Doctor Mearns was directed to act as medical officer, with orders to report for duty on February 1, 1892. By "previous correspondence with Lieut. Col. J. W. Barlow, senior commissioner," he had obtained authority to establish "a biological section of the survey, provided this could be accomplished without additional cost" to the commission. By cooperation with the United States National Museum he was enabled to carry out his designs, and he personally was able to conduct observations along the entire line from El Paso to the Pacific, including San Clemente

[1] Auk, IX, July, 1892, 252–270.

Island, which he visited to carry his investigations to their logical terminus. The work was continued up to September, 1894, except for an interval of a few months in the preceding year, when his time was divided between Forts Hancock and Clark, in Texas. During his work on the boundary line he had the services of one assistant for a considerable part of the time, as well as the voluntary aid of his associates on the survey. As a result of their combined industry about 30,000 specimens were collected and transmitted to the United States National Museum. The collections had been carefully made, to illustrate changes in the animals and plants in the various faunal areas through which the expedition passed, with the view of throwing some light on subspecific variation in them.

At the close of the Mexican boundary work, Doctor Mearns was ordered to duty at Fort Myer, Virginia, with permission to study his collections at the National Museum. In the time at his disposal he made considerable progress in identifying the mammals, and in discriminating the several life zones of the boundary line. In addition to the faunal zones currently recognized he suggested several lesser geographical areas, which he termed "differentiation tracts." He had planned an elaborate report on the biology, geology, etc., based on the boundary collections, and had accumulated a vast amount of data and manuscript for this purpose, but Congress withheld the sum estimated to cover the cost of printing and illustrations, and the project was reluctantly given up. The first part of his report on the mammals, the only one thus far published, was issued in 1907,[1] and contains upward of 500 pages, with many plates and text figures. It includes much introductory matter of a general nature, with an itinerary of the expedition, an account of the life areas, lists of the trees, etc., of the Mexican border, and is an excellent example of the careful and detailed methods of its author.

In the autumn of 1896, he devoted his vacation to field work in the Catskills, and to rambles in the vicinity of his old home. A paper entitled "Notes on the Mammals of the Catskill Mountains, New York, with general remarks on the Fauna and Flora of the Region,"[2] was based on investigations made at this time.

After a few months' duty at Fort Clark, Texas, in 1897–1898, he was commissioned brigade surgeon (later chief surgeon) of Volunteers, with the rank of major, in the Spanish-American War, serving until March 22, 1899, when he was honorably discharged and resumed his regular duties. His next station was Fort Adams, Rhode Island, where he served during parts of 1899–1900. While there he joined the Newport Natural History Society, and took an active

[1] Bull. U. S. Nat. Mus., No. 56, Pt. 1, 1907.
[2] Proc. U. S. Nat. Mus., XXI, 1898, 341–360, figs. 1–6.

part in its work, especially in collecting information relative to the present and former status of the mammalian fauna of the State. Toward the close of the year 1900, he suffered a nervous breakdown, probably complicated by earlier attacks of malaria, and was granted several months' sick leave, part of which time he passed in Florida in an effort to regain his health. Three months or more were spent in camp in the Kissimmee prairie region, and while there, in February, 1901, he received notice of his advancement to surgeon, with the rank of major. Upon his return in May, much benefited by his outdoor life, he stopped at Washington and devoted several weeks to a study of the series of jaguars and other tropical American cats at the National Museum, the results of which appeared in a number of papers published during the next few months.

At Fort Yellowstone, where he was on duty in 1902, he was particularly active in gathering botanical material. It was here that he became aware of the destruction of bird and animal life through the presence of a heavy gas, supposed to be carbon dioxide, which settled in certain depressions and cavities of the earth, causing the death of all small animals that ventured into them. In the course of a few months he detected 16 species of birds, numbering many individuals, that had perished in this manner, and he was of the opinion that "hundreds, if not thousands" died from this cause during the year. He recorded the observations made here in a paper entitled "Feathers beside the Styx";[1] and, before leaving the park, he requested the superintendent to have the most dangerous spots provided with wire screens to prevent the birds entering them.

Military service in the Philippines, which he visited in 1903–1904 and again in 1905–1907, afforded Doctor Mearns his first opportunity to study nature in an entirely new dress. The islands possessed a rich and varied fauna, with many areas still unexplored or but slightly known, while many problems bearing on the distribution of species within the group remained to be solved. He was largely responsible for the formation of the "Philippine Scientific Association," a society organized on July 27, 1903, and having as its chief object the promotion of scientific effort in the Philippine Islands. It was begun under the presidency of Major General Leonard Wood, a broad-minded officer, who encouraged every form of scientific endeavor. Mearns was a most active member of this league from its inception, and his quiet but effective powers of persuasion, and his ability to enthuse others were the means of securing much material and information for later study. During the year covered by his first visit, he served as surgeon in the military department of Mindanao, where his time was fully occupied,

[1] Condor, V, 1903, 36–38.

so much so, that it was often necessary for him to work far into the night to preserve specimens brought in to him during the day. In his official capacity he accompanied eight punitive expeditions against hostile Moros, but even under these circumstances his collections continued to grow, through the cooperation of his associates. Ethnological material, such as bolos and other native implements and weapons, together with various editions of the Koran, were secured on these forays and utilized as specimens. He accompanied General Wood on three trips of inspection to various islands, some of them zoologically unknown and rarely visited, and during parts of June and July, 1904, he ascended Mount Apo, the highest peak in the Philippines, where he made general collections and secured much information of value. In the exploration of Mount Apo he was anticipated by two English collectors, who had made collections there hardly a year before.

Hard work, combined with exposure in a tropical climate, had its effect, and in September, 1904, he was sent to the Army General Hospital at San Francisco, suffering from a complication of tropical parasitic disorders. He visited Washington after he had partially recovered his health, and took advantage of this opportunity to study some of his Philippine material, and in a series of five papers issued in the early part of 1905, he described 6 new genera and 25 new species of mammals, a new genus and 19 new species of birds, besides recording 8 species of birds not previously known from the islands, with notes on other of the rarer forms. Other new types embraced in his collections were made known by experts in several branches of zoology.

On July 20, 1905, Mearns stopped at Guam, on his way back to the Philippines, and here he made the inevitable collection that attended his every pause, however brief, in a new locality. In the few hours spent at Guam he obtained 23 birds and a variety of other material. To him every specimen had a potential scientific value, and if worth picking up at all was worth labeling with its full history. This applied to all material, whether in his own chosen field or not, his theory being that if a specimen proved to be of no interest it could be easily discarded at any time.

During the two years of his second period of service in the Philippines he was enabled to reach many interesting and obscurely known islands, having the good fortune to accompany General Wood on tours of inspection to the northernmost and southernmost points of the Archipelago, but space forbids notice of other than his two chief exploits. In May, 1906, he was placed in command of a "Biological and Geographical Reconnoissance of the Malindang Mountain Group," in western Mindanao, which was organized to explore

and map the region and make collections of its natural products. This expedition, originally consisting of 21 white and [illegible] native carriers, left the old fort at Misamis, on May 9, and experienced many difficulties, ascending one spur of the mountain after another, only to discover that an impassable gorge several thousand feet deep separated it from the main peak. By May 25 the party had become reduced to half its original number, through the departure of various members to the coast. The remainder pushed on, and at 11.30 o'clock on the morning of June 4 reached the top of Grand Malindang, the second highest point in the Philippines, and previously unvisited by civilized man. It was foggy and cold, but Doctor Mearns remained on the summit three days and nights to secure a good series of animal life of that altitude. The return to the coast was comparatively uneventful and occupied only a few days. A good map of the region was prepared, and a number of new animals and plants were discovered, including *Malindangia*, a new genus of birds.

One achievement among Mearns's Philippine experiences stands out more prominently than any other, namely, his ascent of Mount Halcon, which was undertaken at the worst season of the year. This notable expedition, headed by Doctor Mearns, was organized "under the direction and with the support of Major General Leonard Wood," its object being to "determine some feasible route to the mountain, to ascend the highest peak, to secure as much data as possible, and to collect objects of natural history." Elmer D. Merrill, botanist of the expedition, has fortunately given an account of this trip, and the extracts here quoted are from his paper.

Halcon, the third highest peak in the Philippines, is situated in the north-central part of Mindoro. With no known trails leading to it, surrounded by dense forests, cut off from the coast by difficult ridges and large rivers subject to enormous and appalling floods, it stood seemingly inaccessible. Its location is perhaps in the most humid part of the Philippines, where the rains continue for nine months in the year, in a region geographically quite unknown and inhabited by a sparse population of entirely wild and very timid people, and on an island regarding which there is a widespread and generally accepted belief as to its unhealthfulness. Although within 100 miles of Manila and not more than 15 from Calapan, the capital of Mindoro, so far as I have been able to determine it remained unconquered up to the year 1906.

John Whitehead, an English collector, who reached one of the outlying spurs of Halcon in the winter of 1895, wrote of this region:

I have seen a good deal of the Tropics, but I never encountered such deluges, such incessant rain, or such thousands of leeches.

The Mearns party, consisting of 11 whites and 22 natives, left Calapan on November 1 for Subaan, where it began its journey inland. The expedition discovered several uncharted rivers, which had to be forded or crossed on rude bridges constructed by the party, and prog-

ress was impeded by the almost constant rains, the difficulties of trail cutting, and the swarms of leeches, the latter constituting a notorious drawback to travel in the forests of that region. The privations of the journey are graphically set forth by Merrill, who states that the expedition reached the summit on the afternoon of November 22, but remained only long enough to take aneroid readings and deposit a record of the trip. The return to the coast was not without trouble, since nearly 14 days were required to reach Subaan. Carriers sent down in advance for food and supplies had not returned; the remaining members were obliged to carry heavy loads; a bridge made by the party was washed away and had to be rebuilt; blinding rain continued for days without a pause; two men were lost for several days and later discovered in a half-famished state; and all of the party were on short rations. These and other troubles were incidents of the return trip. At length, however, the party reached Subaan, December 5, after an absence of 40 days. The zoological results of the trip were disappointing, since only by the exercise of great effort could specimens be prepared or saved from later destruction by moisture. Furthermore, Doctor Mearns noted that the mountain birds had descended to lower levels to escape the rains, and flocks of them were observed passing up the mountain side when the party was on its return to the coast.

Late in 1907, Doctor Mearns returned from the Philippines and was ordered to Fort Totten, New York, where he remained nearly a year. While at this station he indulged in a garden and derived much satisfaction from growing a variety of vegetables and registering in his notebooks the results of his toil, indicating the treatment, yield and value of each kind planted. It was at Fort Totten that he became aware of the presence of the disease that finally brought his career to an end.

In 1908, President Roosevelt planned an extensive hunting and scientific expedition to Africa, and invited the Smithsonian Institution to participate, with the view of securing the best results in the preservation of both large and small game. The proposition was accepted, and Doctor Mearns was suggested for the position of naturalist. He agreed to undertake the journey, and on January 1, 1909, he was retired, with the rank of lieutenant colonel, but "assigned to active duty with his consent," with orders to "report in person to the President of the United States for duty." Concerning the objects of the expedition President Roosevelt wrote him:

> While our collections will be mainly of mammals and birds, yet if we can add reptiles and fresh-water fish, it will certainly be desirable. While not making a special effort in the collection of insects and plants, it will yet be desirable to do all that can conveniently be done in these directions.
>
> Doctor Walcott recommended you to me as being the best field naturalist and collector in the United States; and as I already knew well the admirable work

you had done I was only too glad to assent to the recommendation, and, accordingly, at his request detailed you to take charge of the scientific work of the expedition. I know no one who could do it as well.

The party, consisting of Colonel Roosevelt, his son Kermit, Doctor Mearns, and Messrs. Heller and Loring, sailed early in March, 1909, and was absent nearly a year. It traversed sections of British East Africa, where Mearns seized the opportunity to collect material on the slopes of Mount Kenia up to the snow line; Uganda, across which he journeyed on foot, to enable him to make better collections and observations; finally passing through the Lado Enclave, down the White Nile to the coast. The course of the expedition and its results are matters of history, and it will suffice here to say that of the upward of 4,000 birds collected, over 3,000 were obtained by Doctor Mearns, who also secured many small mammals, plants, and other objects.

Upon his return to Washington, Dr. Mearns began a general report on the birds and published several preliminary papers describing new forms obtained on the expedition. While thus engaged he was requested by Mr. Childs Frick to undertake another African journey, which was to include Abyssinia and little traveled parts of eastern Africa. Although less physically fitted to undertake difficult journeys than formerly, the advantage of having more material for comparison appealed to him, and he was unable to resist the temptation. He became a member of this expedition, and the latter part of the year 1911 found him again in Africa, from which he returned in September, 1912. The party entered at Djibouti, French Somaliland, and traveled inland to Dire Daoua, thence to Addis Abeba, the Abyssinian capital. From there it worked generally south by way of the Abaya lakes, through the Galla country, making a loop round Lake Stephanie and skirting the south end of Lake Rudolf, and finally reached Nairobi. Part of the territory traversed was previously unexplored, and the liberal collections made over the whole route enabled Doctor Mearns to add greatly to his knowledge of the birds of eastern Africa. In April, 1912, when the expedition was in a remote part of southern Abyssinia, his son, Louis Mearns, a most estimable and promising young man, who had accompanied him on many lesser collecting trips, died in Baltimore, Maryland. The news of this sad occurrence, which was withheld by his family until his return to the United States, proved a severe shock to him.

With largely increased collections—the Frick expedition having added over 5,000 birds to his available material—Doctor Mearns again resumed his studies, intending to work up all of the African series together. He had been relieved from further active duty at the end of the year 1910 and felt he could at last make his plans and move as he pleased. For years he had cherished the desire to settle

down to museum research, to work over his collections and complete reports long projected. The opportunity was now at hand, but, alas! not to be realized. The privations and exposure of his many travels, together with the progress of his malady, had so undermined his system that his vitality had reached a low ebb. He continued at work for two or three years, with ever widening periods of inability to reach his office. Thinking to benefit his condition, he made several short field trips in this period, from which he returned without much improvement, and at length he succumbed, in the midst of his greatest undertaking, surrounded by a wealth of material that was largely the result of his own industry. He passed away at the Walter Reed Army General Hospital, in Washington, November 1, 1916, leaving his mother, widow, daughter, and a large number of friends to mourn his loss.

Doctor Mearns was of an exceedingly generous disposition, one who had no desire to retain the fruits of his labor for his own glory and satisfaction, but preferred to donate them to museums where they would be accessible to all for study. His earlier collections, made up to 1891, went to the American Museum of Natural History, and later ones were given with equal liberality to the United States National Museum. Of shells, and probably other objects collected in large quantity, he distributed sets to various museums, while a series of human skeletons and crania from the cliff dwellings at Fort Verde was sent to the Army Medical Museum. An inkling of the importance of his contributions may be gathered from the statement of Standley (1917), who writes:

> As naturalist of the Mexican Boundary Survey of 1892–93 he collected or had collected under his direction the largest and best representation ever obtained, consisting of several thousand numbers, of the flora of that part of the United States and Mexican boundary which extends from El Paso, Texas, to San Diego, California. Doctor Mearns secured also what is undoubtedly the largest series of plants ever obtained in the Yellowstone National Park, and in addition he collected extensively in the Philippines, Arizona, Florida, Rhode Island, Minnesota, and southern New York. All his collections are deposited in the United States National Museum, and probably no one person has contributed a larger number of plants to that institution.

Hollister, in 1913, referring to Philippine mammals, said that of 1,464 specimens in the National Museum, "probably by far the largest collection from the archipelago in any museum," Doctor Mearns had given 1,012. More impressive figures may be cited in the case of birds, when it is known that more than one-tenth of the total number of specimens of birds in the United States National Museum were either collected or contributed by him.

The published writings of Doctor Mearns number about 125 titles, chiefly on biological subjects, although medicine, archaeology, and biography are also represented. Fifty or more new species of animals

and plants have been named in his honor, as well as three genera, the latter constituting a rather unusual distinction. Mearnsia, a tree of the myrtle family, is a native of the slopes of Mount Halcon, and the same name has been conferred on a rare swift from the island of Mindanao, while Mearnsella commemorates a genus of fishes from the last-named locality.

Doctor Mearns was a patron of the American Museum of Natural History; associate in Zoology of the National Museum; correspondent of the Academy of Natural Sciences of Philadelphia; fellow of the American Ornithologists' Union; member of the National Geographic Society, of the Biological Society of Washington, of the Linnean Society of New York, and of various other societies.

For one who had engaged in many difficult journeys, Doctor Mearns was of rather frail build, not more than 5 feet 4 inches in height, and probably never weighed much in excess of 140 pounds, but he was blessed with a spirit of determination that enabled him to accomplish nearly every task he undertook. Withal, he was modest and unassuming in demeanor and seldom referred to his own exploits, but was a good auditor and always interested in the experiences of his friends. He avoided arguments and never indulged in criticism of others; was fair and impartial in his appraisement of men. He was always willing to seek advice and give weight to the opinions of others. Serene and placid in disposition, cheerful and optimistic in temperament, he was fond of the beautiful in nature and art, even of poetry, yet philosophical and analytical and systematic by nature. As a friend, he was sympathetic, generous, steadfast, and intensely loyal.

WILLIAM BULLOCK CLARK.[1]

Dr. William Bullock Clark, professor of geology in the Johns Hopkins University, eminent for his contributions to geology, died suddenly from apoplexy on July 27, 1917, at his summer home at North Haven, Maine.

William Bullock Clark was born at Brattleboro, Vermont, December 15, 1860. His parents were Barna A. and Helen (Bullock) Clark. Among his early ancestors were Thomas Clark, who came to Plymouth, Massachusetts, in the ship *Ann* in 1623 and who was several times elected deputy to the general court of Plymouth Colony; Richard Bullock, who came to Salem, Massachusetts, in 1643; John Howland, a member of council, assistant to the governor, and several times deputy to the general court of Plymouth Colony, who came to Plymouth in the *Mayflower* in 1620; John Tilly, who likewise came in the *Mayflower;* and John Gorham, captain of Massachusetts troops in King Philip's War. Among later ancestors were William Bullock, colonel of Massachusetts troops in the French and Indian War, and Daniel Stewart, a minuteman at the Battle of Lexington in 1775.

Clark studied under private tutors and at the Brattleboro High School, from which he graduated in 1879. He entered Amherst College in the autumn of 1880 and graduated with the degree of A. B. in 1884. He immediately went to Germany and from 1884 to 1887 pursued geological studies at the University of Munich, from which he received the degree of doctor of philosophy in 1887. Subsequently he studied at Berlin and London, spending much time in the field with members of the geological surveys of Prussia and Great Britain.

Before leaving Munich Doctor Clark was offered and accepted the position of instructor in the Johns Hopkins University. He was instructor from 1887 to 1889, associate from 1889 to 1892, associate professor from 1892 to 1894, and professor of geology and head of the department from 1894 until the time of his death. He had been for a long time a member of the academic council—the governing body of the university—and always took a very active interest in its affairs, acting as one of the committee of administration while the university was without a president.

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In 1888 he was also appointed an assistant geologist on the United States Geological Survey and detailed for work on the Cretaceous and Tertiary formations of the Atlantic Coastal Plain. At the same time he was requested to prepare the correlation bulletin on the Eocene, one of a series of reports which were presented to the International Geological Congress in Washington in 1891. Professor Clark spent the summer of 1889 in a study of the Eocene deposits of the far West, while the remaining period was occupied in the investigation of the Eocene formations of the Atlantic border. He was advanced to geologist on the staff of the United States Geological Survey in 1894 and held this position until 1907, since which time he has acted as cooperating geologist.

Professor Clark organized the Maryland State Weather Service in 1892, of which he was appointed the director and held the position continuously until his death. In 1896 he organized the Maryland Geological Survey, and had been State geologist since the establishment of that bureau. The geological survey was enlarged in scope in 1898 by the addition of a highway division, which was instructed to investigate and report on the conditions of the roads of the State and the best means for their improvement, and Professor Clark and his associates through their publications and addresses aroused much interest in the subject throughout the State. In 1904 the duties of the highway division were much increased by the appropriation of $200,000 annually, to be met by a similar amount from the counties, for the building of State-aid roads by the survey. A sum exceeding $200,000 was also subsequently appropriated for the building, at the expense of the State alone, of a highway connecting Baltimore and Washington. The duties of the highway division were transferred in 1910 to a newly organized State roads commission, of which Professor Clark was made a member and which position he held until 1914. Nearly $2,000,000 had been expended, however, by the State geological survey in the supervision and building of roads up to the date of the transfer.

Under an act of the legislature passed in 1900 Professor Clark was appointed commissioner for Maryland by the governor to represent the State in the resurvey of the Maryland-Pennsylvania boundary, commonly known as the Mason and Dixon line. This survey was completed four years later and an elaborate report prepared. In 1906 he was made a member of the Maryland State Board of Forestry, and elected as its executive officer, which position he held at the time of his death. The governor appointed him in 1908 a member of the State conservation commission.

Professor Clark organized and directed the preparation of the official State exhibits of Maryland mineral resources at the Buffalo, Charleston, St. Louis, Jamestown, and San Francisco expositions in

1901, 1902, 1904, 1907, and 1915. These exhibits attracted much attention at the time and received a large number of conspicuous awards. The exhibits have been permanently installed as a State mineral exhibit at the statehouse in Annapolis.

When President Roosevelt invited the governors of the States to a conference on conservation at the White House in May, 1908, it was arranged that each governor should appoint three advisers to accompany him. Professor Clark was one of the Maryland advisers and took part in the conference.

After the great Baltimore fire in 1904 the mayor of the city appointed Professor Clark a member of an emergency committee to prepare plans for the rehabilitation of the burnt district and for several months he served as vice chairman of the important subcommittee on streets, parks, and docks, whose plans resulted in the great changes subsequently carried out. The following year he was appointed by the mayor a member of a committee to devise a plan for a sewerage system for the city which has resulted in the building of the present modern system of sewers. Again in 1909 the mayor also appointed him a member of a committee for devising a plan for the development of a civic center for Baltimore.

Since 1901 Professor Clark had been president of the Henry Watson Children's Aid Society of Baltimore and was a delegate to the White House conference called by President Roosevelt in February, 1909, to consider the subject of the dependent child. He was also a member of the executive committee of the State tuberculosis association and a vice president and chairman of the executive committee of the federated charities of Baltimore.

Numerous scientific societies elected him to membership, among them the National Academy of Sciences, of which he was chairman of the geological section, the American Philosophical Society, the Philadelphia Academy of Natural Sciences, the American Academy of Arts and Sciences, the Deutsche Geologische Gesellschaft, the Washington Academy of Sciences, Paläontologische Gesellschaft, and the American Association for the Advancement of Science. He was councilor and treasurer of the Geological Society of America at the time of his death. In 1904 he was elected a foreign correspondent of the Geological Society of London. He was also president of the Association of State Geologists. Amherst conferred on him the degree of LL. D. in 1908. He had numerous offers from other institutions, perhaps the most important being the professorship and head of the department of geology at Harvard University, but all of these were refused, and his devotion to Hopkins and the ideals for which it stood was unswerving.

At the time of the International Geological Congress in St. Petersburg in 1897 Professor Clark was an official delegate from the

United States and spent several months in an extended trip through Russia and its Provinces. In 1906 he spent the summer on an expedition to central Alaska, visiting the region to the north of Prince William Sound. He traveled extensively in western America and Mexico, reaching distant portions of the western Sierra Madre district.

With the outbreak of the war Professor Clark became actively interested in problems of defense and economic preparedness. He was appointed a member of the National Research Council and was chairman of the subcommittee on road materials and a member of the committee on camp sites and water supplies. He was also chairman of the committee on highways and natural resources of the Maryland Council of Defense.

Professor Clark made numerous contributions to geological literature, his work being confined largely to the Cretaceous and Tertiary formations of the Atlantic Coastal Plain and the Carboniferous deposits of the central Appalachian region. Professor Clark's chief paleontological interest was centered in the Echinoidea, to the elucidation of which group he published several monographs. One of his monuments will be the series of reports of the Maryland Geological Survey, which set a new standard for State publications both as to subject matter and bookmaking. The systematic reports in which he was most interested will be of perennial service to science.

He was a member of numerous clubs, including the University, Maryland, of which he was a vice president, Baltimore County, Johns Hopkins, and City Clubs of Baltimore and the Cosmos Club of Washington.

He was married October 12, 1892, to Ellen Clarke Strong, daughter of the late Edward A. Strong, of Boston, and had four children, Edward Strong, Helen, who was recently married to Capt. H. Findlay French, Atherton, and Marion, all of whom survive him.

Professor Clark's administrative ability and professional attainments are largely responsible for the extensive development of Maryland's mineral resources, and his loss will be severely felt in all quarters. He was always keenly interested in the educational value of the work of the various State bureaus which he directed and had just finished writing a geography of Maryland for school-teachers. At the time of his death he was engaged in writing a report on the underground waters of the State and another on the coals.

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